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THE JOURNAL

OF THE

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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THE VENTILATION OF PASSENGER CARS ON RAILROADS.*

BY DR. CHAS. B. DUDLEY,
Chemist to the Pennsylvania Railroad Company, Altoona, Pa.

I dare say every one who has spent any time in a railway car has wondered to himself why in the world the railroad company does not ventilate its cars better. The query is a very natural one, but I am sure if the general public knew how much the subject of the ventilation of passenger cars on railways has been studied, and how difficult are the problems presented, they would be more lenient in their criticisms than they sometimes are.

Of course, the first step in the study of a problem of this kind is to find out what is the present state of affairs. Professor Ripley Nichols, of the Massachusetts Institute of Technology, some fifteen or more years ago, made a number of analyses of the air from railway cars on the Boston and Providence Road, for the Railway Commissioners of the State of Massachusetts. Also, about fifteen years ago, a system of ventilation of passenger cars was developed by a gentleman who had so much influence back of him that he had a car constructed which was sent to Altoona by the officers of the Pennsylvania Railroad, with instructions to make such experiments as would demonstrate whether that car was better ventilated than the standard passenger car of the road. In connection with the experiments on that car we made analyses of the air from passenger coaches three times; that is, of three different samples. The results obtained both by Professor Nichols and ourselves indicated that the present passenger coach on most of the railways of the country gets into it and out again—which practically constitutes ventilation—somewhere from one-eighth to possibly a tenth as much fresh air per hour as it ought to get. It is rather interesting that Professor Nichols' analyses and our own very closely coincide; and it is also quite interesting to know that Professor Nichols analyzed the air from smoking-cars and found no greater amount of carbonic acid in the air from these cars than from the ordinary passenger coach. I am not aware that any analyses have ever been made of the air of Pullman coaches.* Still further, two or three years ago we spent nearly the whole winter with a passenger coach on the Pennsylvania Railroad, trying to study and develop a system of ventilation.

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*A Lecture delivered before the Franklin Institute. Friday evening. January 22, 1897.

Notwithstanding this study, and notwithstanding the amount of effort and the cry that is in the technical papers, and sometimes in the daily papers, in regard to the ventilation of passenger cars, I am very sorry to have to say to you, frankly and honestly, that it is not possible at the present time to properly ventilate a passenger car on a railway. No system is at present known by which this can be successfully accomplished. If I succeed in what I have attempted to-night, you will, before I am done, understand why.

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*Since this lecture was delivered. a note from Wm. Forsyth, Mechanical Engineer of the C., B. and Q. R. R., calls attention to the fact that the air from Pullman cars has been analyzed, the results obtained being given in the Proceedings of the Master Car Builders' Association for 1894, pages 234-241.

Perhaps I may best bring out what I have in mind by asking myself a series of questions and then answering them for you. Accordingly, the first question which I shall ask myself is, what is the problem that we are undertaking to solve when we attempt to ventilate a passenger car? It is, perhaps, not too much to say that no problem in engineering has ever been undertaken by mechanical engineers, or ventilating engineers, if you choose, or chemists, or scientific men, that is so fraught with difficulties as the ventilation of passenger coaches on railroads. Let us see what the problem is.

An ordinary passenger coach contains about 4,000 cubic feet of space—about one-fifth the size of this room, as near as I can estimate. It is proposed to take into this small space at least sixty persons; to keep them in this space continuously, without allowing them a chance to get out, for four hours or longer; to keep these persons warm enough for their comfort in winter, and to supply them with enough fresh air to ventilate the car properly, and at the same time exclude, throughout the year, smoke and cinders, and, in the summer season, dust. I think it is fair to repeat that no problem has ever been committed to the experimental and mechanical engineering departments of the Pennsylvania Railroad since I have been connected with it, now a little over twenty years, so difficult of solution as this problem of car ventilation.

The next question I shall ask myself is, is a system of ventilation on passenger cars essential throughout the year? Do you need to ventilate your cars in summer? Why not open your doors and windows and have all the fresh air you want? This seems, possibly, a very satisfactory solution of the problem, and if one state of affairs could be brought about, which, however, we cannot control, there would be no necessity for anything more than a system of ventilation in the winter season. That state of affairs is this: If the wind always moved at right angles to the direction of the train, you would have no difficulty, for the smoke and cinders and dust would then always be blown away from the cars, and doors and windows could be left open at pleasure. But the wind does not always blow crosswise to the direction of the train, and sometimes there is no wind at all, so that it frequently results that the motion of the train itself brings the smoke and cinders directly from the locomotive back to the coaches. Still further, on roads using dirt or gravel ballast, the amount of dust in the air is sometimes something appalling. In reality, therefore, our problem is to provide a system of ventilation that in the summer season will exclude dust, in the winter season will warm the air properly, and throughout the year will keep out smoke and cinders. We must, therefore, study the problem both from the summer and winter standpoint.

Again, can we have a ventilating system apart from the heating system? I answer that in the course of the years that this problem has been before the experimental departments of the Pennsylvania Railroad, we have been called upon to investigate a number of different systems. It apparently seems to many who have not studied the problem sufficiently, that it is only necessary to make a hole in a car and let the fresh air in, and you have a system of ventilation. Some of the systems that we have examined have practically been very little more than this. The present system of ventilating Pullman cars consists simply in letting cold air into the car through the deck sash near the top of the car, which cold air mixes with the warm air in the car, and may pass out through the ventilators over the lamps, or possibly out through the deck sash on the other side. Other so-called systems simply put ventilators in the deck to draw air out of the car, allowing it to find its way into the car as best it may. It is, perhaps, hardly necessary to say that such attempts can hardly be regarded as worthy of the name of a ventilating system. To our minds, the first requisite, the first essential feature of a system of car ventilation in our climate, is the heating system. There is very little use, if we are right, in trying to study the problem without studying the two systems together. Accordingly, in all our studies, we have tried to develop the two systems in connection with each other, and our belief is that any system of ventilating passenger cars that does not warm the air that is taken into the car, will result in failure. No human being can endure to have the amount of fresh air required for successful ventilation taken into a car in winter, unless that air is warmed.

Just here another interesting question arises, viz.: what is the test of good ventilation? How do you know when a room, or a car, if you choose, is well ventilated? It is obvious that we must have some measure of the ventilation, or else we cannot tell whether we are taking too much or too little air into the car. We have followed, in the studies which we are putting upon this question of the ventilation of passenger cars, Parke's Practical Hygiene, which, as we understand it, is the standard on hygiene for the British army. The seventh edition gives, perhaps, the best summary now available of the information we now possess, on the general subject of ventilation. In this edition it is stated as a test of good ventilation, that any space, be it a room, a passenger car, a theatre, or whatever you choose, is well ventilated when a person coming into that space from outside fresh air detects none of the odor characteristic of badly ventilated spaces. But what measure have we of what is characteristic of no odor? Odors cannot be measured. Fortunately, however, one at least of the substances accompanying the odor characteristic of bad ventilation, and which is proportional to the odor, can be measured.

Let me see if I can make this clear. Three things are continually given off from our bodies, namely, carbonic acid, water vapor and organic matter. Every time we breathe, we breathe out some carbonic acid, we breathe out some water vapor, as every one knows who has been out on a cold morning, and we also breathe out, there is exhaled from our bodies, a certain substance, which, for want of a better name, is simply called organic matter, and which is believed to be the source of the odor. Of these three substances, carbonic acid is easily measurable. That is the substance we measured when we made analyses of the air in the cars, or that Professor Nichols measured in his analyses, and it is customary to take the amount of carbonic acid in the air as the measure of good ventilation.

Many years ago, before this latest test that I have already mentioned here to-night was introduced, it was customary to place an arbitrary limit on the amount of carbonic acid that should be allowed in the air, in spaces which were said to be well ventilated. That is to say, twenty years ago, if the amount of carbonic acid in the air in any given space did not exceed 10 cubic feet in 10,000 of the air, that space was said to be well ventilated; but later studies have changed this view. A very large number of analyses of air have been made to find the amount of carbonic acid that is characteristic of the air when you can just begin to detect an odor. In this book which I have here, Parke's Practical Hygiene, there is given a summary of a very large number of such analyses, giving the amount of carbonic acid that is in the air when one can just begin to detect an odor. The average of these analyses indicates that when two parts, or 2 cubic feet of carbonic acid that comes from our bodies, or the bodies of animals, in 10,000 of air is found, one can just begin to detect an odor in a closed inhabited space. Therefore, 2 cubic feet of carbonic acid given off by human beings or animals in a closed space, in 10,000 cubic feet of air, is taken as the test or measure of good ventilation. I should say for your information, perhaps, that the air in different parts of the world and from many different places has been analyzed a good many times for carbonic acid. From these it is found that there is a certain normal amount of carbonic acid in almost any air. The air in this room, even if the windows were wide open and the room vacant, would contain a certain small amount of carbonic acid. The average of these analyses (they vary somewhat)—in towns the amount is larger than it is in the country—but the average amount is about 4 cubic feet in 10,000; that is, 10,000 cubic feet of air contain normally 4 cubic feet of carbonic acid. Now, if we add to that the 2 that come from our bodies, we would find in what would be called a well-ventilated space an amount of carbonic acid not exceeding 6 cubic feet in 10,000.

Taking then this 2 cubic feet that comes from human beings as the measure of ventilation, we are prepared to take another step forward in our study of the problem. A good many experiments have been made by different investigators as to the amount of carbonic acid that a human being gives off per hour. It has been found that men give off more than women; children less than either; that a man in vigorous work gives off more than a man in idleness; but the average of a mixed community—men, women and children, as they occur—is given as six-tenths of a cubic foot of carbonic acid given off from our bodies, both by the skin and from the lungs, per hour per person. So this is another of the foundations on which we are building up our scheme for the ventilation of passenger cars; namely, six-tenths of a cubic foot of carbonic acid given off by the average of persons from a mixed community such as we carry in our cars, per person per hour.

From these data it only takes a little arithmetic to get some sort of an idea of the answer to the next question which I am going to ask myself; namely, how much air per hour do we need to take into a car and out again in order to have that car properly ventilated? I will not make the calculation; but it is very simple. The data are, if 2 cubic feet of carbonic acid can be added to 10,000 cubic feet of air and still have good ventilation, how many cubic feet of air per hour must be brought into a closed space to bring six-tenths of a cubic foot per person down to a limit of 2 cubic feet in 10,000? If you made this calculation you would find this figure, viz.: that every hour after the first one, the first hour being occupied in saturating the space in which the persons are, 3,000 cubic feet of air per person per hour must be taken into any closed space in order to dilute the carbonic acid that is given off by an average from a mixed community down to the limit required for good ventilation, which is 2 cubic feet in 10,000, which again is the limit when an odor just begins to be perceptible to a person coming into any closed space where human beings are from the outside.

Now, let us take another step. 3,000 cubic feet of air per person per hour are required; but we have 60 people in a car, and 60 times 3,000 is 180,000 cubic feet of air, that must be taken into a car per hour, on the basis of this calculation which we have just made. What does that mean? It means that we must change the total air in that car forty-five times in an hour, or about once in eighty seconds. I say to you very frankly that we have not attempted in our experiments to reach any such figure as this. When we came to get our foundations on which to start our experiments and noted this prodigious figure of 180,000 cubic feet of air per hour required, according to the theory of the best authorities in the books, that we ought to have in order to ventilate our cars well, we were simply appalled. It is practically out of the question to take that amount of air through a passenger car per hour, and I hope a little later to show you why.

I should say at this time, perhaps, that some two years ago experiments were carried on for some time, by a committee consisting of Dr. S. Weir Mitchell and Dr. J. S. Billings, the results of which were published by the Smithsonian Institution. The object of these experiments was to find out to what the drowsy feeling that we have when in an ill-ventilated place was due, and also to find out what produces death from lack of ventilation. Those studies seem to indicate that the amount of fresh air that I have mentioned, namely, 3,000 cubic feet of air per person per hour, is large, and that possibly a smaller figure would be satisfactory. These authorities, however, are very cautious; they give us no definite figures. They apparently could not prove the existence of, or at least could not isolate any poisons in the air that would produce death. They seem to indicate that the drowsy feeling is due principally to increase of carbonic acid and diminution of oxygen. And, finally, they say in so many words that it would be a mistake to assume from their experiments that the ordinary figures applying to ventilation are widely in error.

Now allow me while I ask myself another question. How much heat would be required to heat 180,000 cubic feet of air per hour from the temperature of zero, which is not at all uncommon in our winter here, up to a livable temperature in a car? I have spent some time over this query, but am compelled to utilize, however, the results of other people's experiments somewhat. The best information that I can get on the subject is that the heat from a pound of steam at a pressure of 15 pounds per square inch is sufficient to heat 6,700 cubic feet of air from zero to 70° Fahrenheit. If we follow that through and find the amount of heat that would be required for a train of, say, twelve cars—which is not at all uncommon when traffic is good—we will be led to the result that it would take , in order to warm the air that would be required to ventilate the cars on the calculations that we have already made about 3 per cent. of the power of the locomotive; in other words, it would require about 400 pounds of steam per hour, and the locomotive of the largest type that is now on the Pennsylvania Railroad evaporates about 14,000 pounds of water an hour. This problem we have not met very seriously yet.

We do find, however, with some of the large passenger trains because of the speeds required to be maintained, that the drain on the locomotive is sometimes a little serious, especially when we are doing other things with the locomotive, such as running electric light plant in the baggage car. In the winter season, with six Pullman cars and trying to make high speed, it is sometimes difficult to maintain the steam pressure owing to this drain. The question of the amount of the heat required, however, is not one that ought to enter very strongly into our problem, because if we must have a large amount of heat to warm the air we must furnish it. That is all that can be said on this point. But it is certain that we could not warm twelve cars on the basis which we have been figuring, short of using from 3 to 3½ per cent. of the total evaporation of the locomotive, for heating purposes alone. Still further, I have in the above calculation simply planned to heat the air up to 70°; but as everybody knows, a car above the belt rail or 3 or 4 feet from the floor largely consists of windows, and there are constant leakages around these and the doors, so that it is probable that the air that leaves the heater system would have to leave it perhaps 10° and possibly 20° higher than 70°, on account of these leakages and on account of the large amount of heat lost by the glass. If we had to heat it 90° F., it would possibly take 500 pounds of steam per hour per train of twelve cars, and make a still further draft on the locomotive.

I said a few moments ago that in our experiments we had made no attempt to get anything like so large an amount of air into our cars as 180,000 cubic feet an hour. We had a very careful consultation of the best experts we had on this subject before we began these experiments. I counselled this: "Let us not attempt to do more than half what theory calls for." A recent writer in one of the railroad technical papers calls for 60,000 cubic feet per hour, and wants to have it made by law requisite that every railroad car shall be provided with appliances that will give at least 60,000 cubic feet of air per car per hour, or 1,000 cubic feet of air per person. Just what will be the amount that we will ultimately be able to secure is still an unsolved problem, In most of the experiments we made two years ago, we worked on the basis of securing 90,000 cubic feet of air per car per hour.

I have had several drawings made, shown in Plates I and II, to give you, approximately, an idea of the state of the problem, Let me say that at present the only thing that can be called a system of ventilation in the passenger cars of the Pennsylvania Railroad consists in taking air in through a hood, shown at *a* in Plate I, which air passes down through a sheet iron pipe *b* and is delivered inside the casing *c* surrounding the stove *d*. A vertical diaphragm or partition *e f* divides the space between the stove and casing into two parts. The air is received at the bottom of this space, as is shown by the arrows, passes up one side of the partition and down the other, being heated by contact with the outside surface of the stove during this passage, and is then delivered to a trunk or box *g*, which extends nearly the whole length of the car. From this trunk, the heated air finds its way out through the registers *h h*, situated between the seats into the body of the car, and, finally, out into the open air, through the deck sash *i i*. Of course, also a small amount of the warmed air passes out of the ventilators over the lamps or gas jets. There are two stoves in each car, and two intakes for air, situated at diagonally opposite corners of the car. Several valves *j j* in the hood always secure the passage of the air down the pipe *b*, whichever way the car is moving. This system of warming and ventilating is known as the Spear stove system. A little study shows that this system is open to two serious objections. These are, first of all, the stove. Everybody knows that we are trying to get rid of the stove for car heating, on account of the danger in case of accident. It is not necessary to say much about the deadly car stove. The newspapers do enough of that. Suffice it to say that one of the difficulties of the present system is the stove. The other difficulty is this, and a rather peculiar one it is: When the car is running and the wind is not too strong in the wrong direction, air is forced into the hoods, and thence into the car in the manner described, with the result that the car is fairly well warmed and ventilated. But when the car stands still, or when the wind in the opposite direction is just equal to the speed of the train, what takes place? The air goes in the other direction. The source of heat being higher than the outlets into the car, it is obvious that when the car is standing still, the air currents will move up through the pipe *b* instead of in the opposite direction, as is desired. And this is what we actually find to be the case.

Our studies have been concerned, however, principally with the ventilation of steam-heated cars. The constructions used I may explain, by reference to Plate II. The same hood *a*, on the top of the corner of the car, is used for an intake, as was the case with the Spear Stove System. The air entering this hood passes down through the pipe *b* into a space *c* below the floor, bounded by the floor, the false bottom, the outside sill and the first intermediate sill. This space is about 8 by 14 inches, and extends the whole length of the car. The heater pipes *d d* are situated above the floor in the same trunk that was used to carry and distribute the warm air in the Spear stove system. These pipes are filled with flanges as shown, to increase the surface. It is, perhaps, not necessary for me to go into the heating system further than simply to say that each side of the car has a certain amount of pipe of this kind, running the whole length of the car, which contains steam, of a pressure, say, of from 15 pounds down to no pressure at all, and even a vacuum. We use what is called the return system of heating; that is to say, underneath the car are two parallel pipes, one of which brings the steam from the locomotive, and the other carries the condensed water back to the locomotive again, and so we call our system the return system; that is, we return the condensed water to the locomotive instead of pouring it on the ground. In order to get this water back there is a pump on the locomotive, and under certain conditions the suction may be strong enough so that instead of having a pressure in the heating pipes, we may have a vacuum.

Returning now to the air which we left in the conduit or space underneath the floor, it will be observed that there are a number of apertures *c c* through the floor, directly under the heater pipes. Through these apertures the air passes into the trunk containing the heater pipes, is warmed by contact with these pipes, and then passes out of the apertures *f f* in the trunk into the car. These apertures in the trunk extend the whole length of the car, both between and beneath the seats. From the main body of the car, the air passes out of the ventilators *g g* situated on the top of the upper deck.

The first experiment that we made after the car was fitted up with this device consisted in observing which way the currents would flow when the car is standing still. Quite to our gratification we found them moving in the right direction, namely, when heat is in the car, air passes into the hood *a* down through the pipe *b* into the space or conduit below the floor, thence up through the floor, over the heating system, and out into the body of the car, and, finally, out through the ventilators. It is clear I think why this should be so, since the exit of the ventilators is some 2 feet higher than the topmost point of hood *a*.

So one of the difficulties that was characteristic of the old Spear stove system has been apparently overcome very satisfactorily by this new scheme.

At first the apertures *c c* through the floor underneath the heater system were about 4 inches long and about ¾ inch wide and there was one opposite each seat. Also we had at that time only six ventilators in the upper deck. With a coach fitted in this way we made experiments as follows: We would load the car to its full capacity with men from the shops, the reason for that being that we could take a foreman along and

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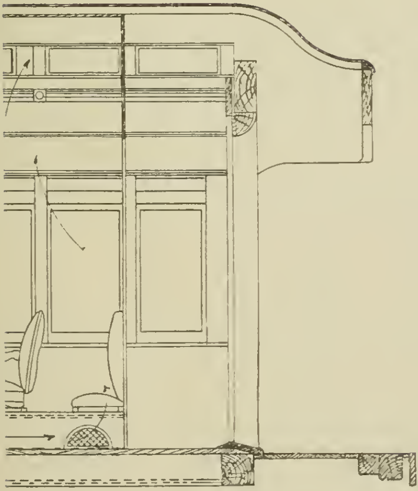

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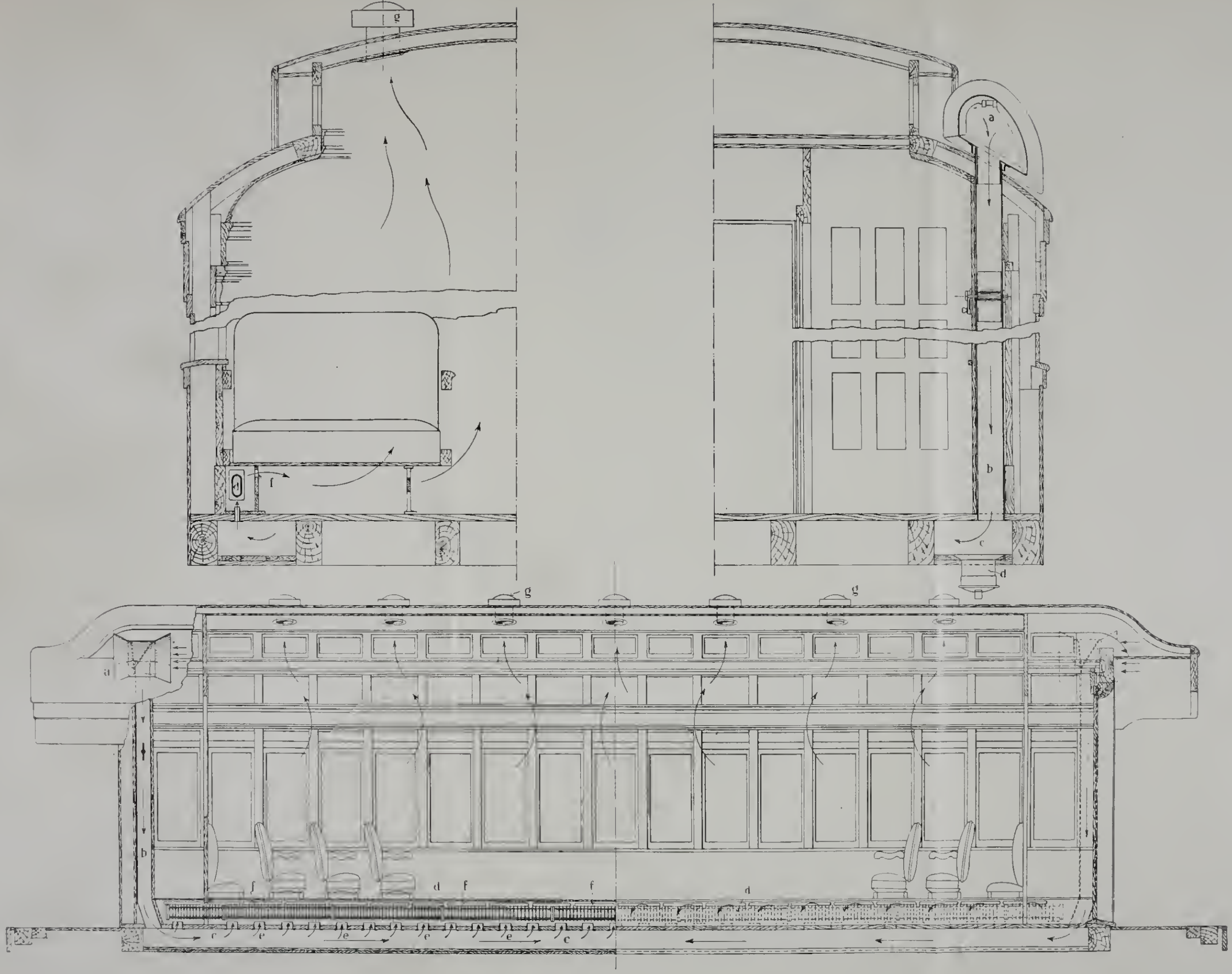
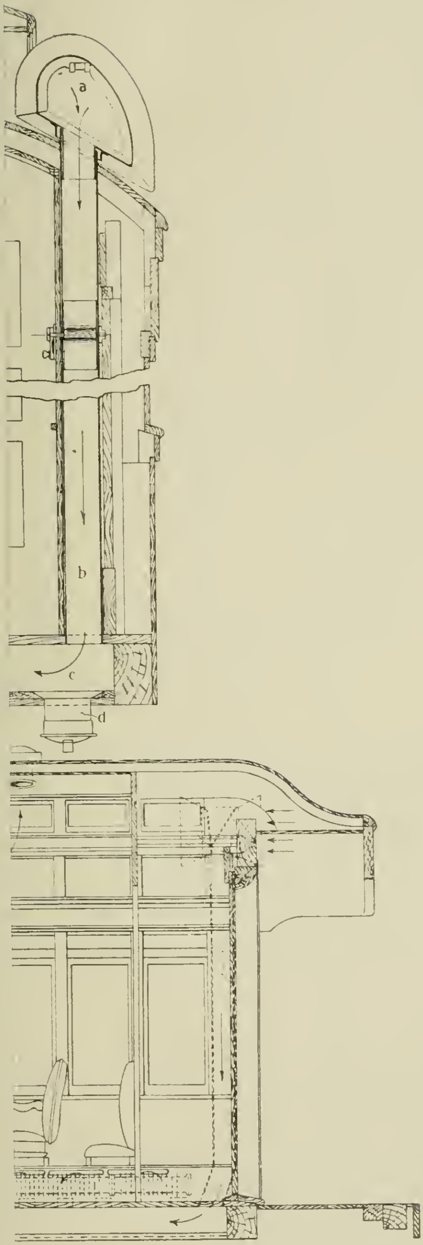


PLATE II.—SHOWING SECTIONS OF STEAM HEATED PASSENGER COACH ON PENNSYLVANIA RAILROAD, AS MODIFIED FOR EXPERIMENTS ON CAR VENTILATOR.



EXPERIMENTS ON CAR VENTILATOR.

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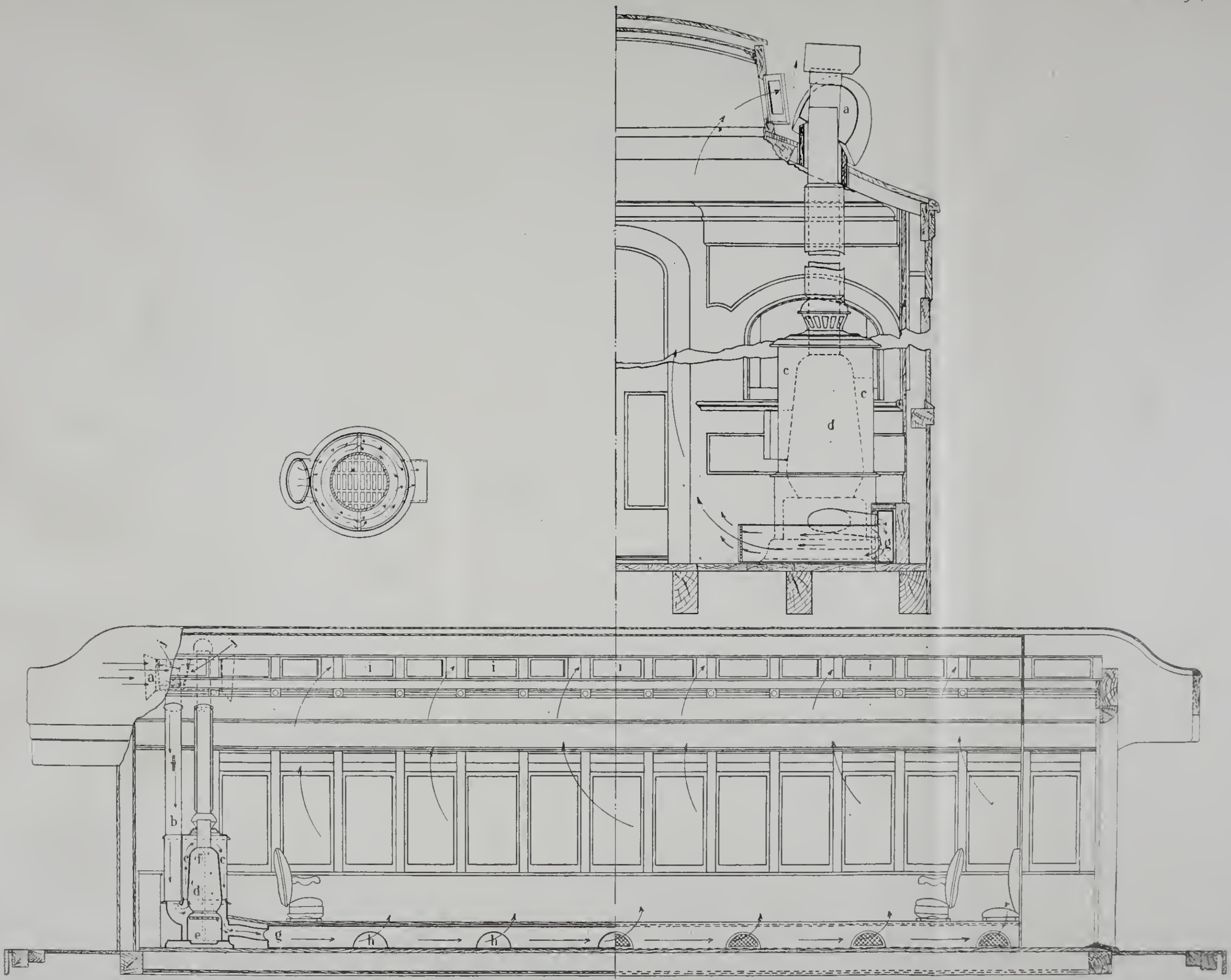

PLATE I.—SHOWING SPEAR STOVE SYSTEM OF HEATING AND VENTILATING PASSENGER CARS, NOW IN USE ON PENNSYLVANIA RAILROAD.

control the men in a way to secure the conditions we sought, and know at all times that we had those conditions. We made a trip to Johnstown, some 35 miles from Altoona, and back again. When we got pretty well over towards Johnstown, allowing neither doors nor windows to be opened during the trip, we took some samples of air in rubber bags, with a little hand bellows, walking the whole length of the aisle back and forth, until the bags were filled, several gallons of the air being taken in each case. Then we stood still on the track for about half an hour, without opening doors or windows, to see how well we ventilated when standing still, and took another sample. Then we put the locomotive on the other end of the car, and when we got nearly back to Altoona took a third sample. Those samples were analyzed several hours after the return from the trip, and we found that we were getting on the first trip about 500 cubic feet of air per person per hour, instead of 1,500, as we desired. Standing still we got about 340 cubic feet per person per hour.

We then made some modifications, increasing the size of the apertures underneath the heating system, and made another trip in exactly the same way; and in that case we got about 600 cubic feet of air per person when we were running and about the same when we were standing still, as in the previous trip.

It became evident from these experiments that we were not getting anything like enough air through the car; and we began then a systematic study to find what part of the passageways limited the flow. We first increased the number of apertures in the floor and enlarged their size until we finally reached this point; namely, we put an aperture 4 inches long and 1¼ inches wide every other 4 inches for the whole length of the car under the heater system; in other words, we had 4 inches of aperture, 1¼ inches wide, then 4 inches of floor, then 4 inches of aperture, and so on, on both sides of the car.

Also we increased the intakes *b* from 8 inches square to 14 inches square, and instead of having one on one corner, and one on the diagonally opposite corner, we put one on each corner. Then instead of having six ventilators in the top of the car, we put on twenty. I have given you the final result of a number of successive trips, modifications being made from time to time. With these appliances what did we obtain? With these appliances it is easy to get 90,000 cubic feet of air per hour through the car. But unfortunately here is where we struck a snag, namely, we could only warm that air about 40° above the outside air. When the temperature is zero, it is perfectly clear that the car was uninhabitable for passengers. That was a serious difficulty, as you will all agree.

In order to overcome this difficulty, we planned one further modification, but further study showed that this modification was impracticable.

It is evident, since the trunk or box containing the heater pipes is small, since the passage of the air through this trunk is very rapid, owing to the large volume per hour, and especially since the cold air impinges against the heater pipes, only about half their length, owing to half the space only being apertures, that it is a reasonable query whether we are utilizing our heating system to the best advantage. Does the air that comes in through these apertures utilize that portion of the heater system between the two apertures? My hearers may say, why didn't you make your aperture continuous, from one end of the car to the other? This is what we planned to do, but on a little study, we found that it would be hazardous to cut the whole length of the floor system completely through. The floor system is necessary to the strength of the car. It holds the outside sill to the first intermediate, and is really a very important element in the strength of the car, and to cut through the floor the whole length, would so greatly weaken it, that we did not venture to try it. So we had to stop at this point; namely, we can take 90,000 cubic feet of air per hour into the car and out again, but we cannot warm it with our present heater system and our present means of utilizing it, and that is exactly where we stand to-day. Of course, the problem is not abandoned; we have not given up the question; we are now studying whether a continuous slot through the whole length of the car would warm that amount of air. Those experiments are being made off a car, so that we can control the conditions. But I may be allowed to repeat, we have reached the point where we can get half as much air as theory calls for into a car and out again; but we cannot warm it.

I will only take a few moments more of your time. I want to give you one or two points that are rather interesting to me; and that seem to throw a little side light on the problem. During our experiments we had five or six thermometers hanging from the baggage racks for getting the temperature at different points in the car; and we had anemometers to measure the air currents, and we had a gauge on the heater system, so that we could tell what was going on inside the heater system.

During one of the trips we struck a very peculiar state of affairs; namely, the rear end of the car was 10° to 20° colder than the front end. This was a good deal of a puzzle for a little time; and, really, it was a thing we could hardly account for; but after a little study we found this very interesting state of affairs: As I told you, we had some twenty ventilators on the car. These ventilators are so made that when a current of air is moving at right angles to the axis of the ventilator, air is drawn out of the space with which the ventilator is connected. We found that with twenty ventilators on the car the suction was a little stronger than the supply. The front ventilators, acting first, made such a vacuum in the car that the regular intakes could not fill it and a current of cold air actually came down through some of the rear ventilators into the car. On closing some of the ventilators the difficulty disappeared. I think this has a bearing on the problem of ventilation, in this way: namely, that you must make your intakes to supply fresh air equal to your exits, or you will have the same difficulty. Some persons have thought that all that was necessary to do was to put ventilators on a car and let the air come in wherever it could. That was tried on some cars, and it was found in the winter season that the ventilators must be closed.

I said some time earlier in the evening that one of our problems was to exclude smoke and cinders and dust. That part of the problem we have as yet hardly touched. I don't know to-day of any practicable means by which that can be done. I will say for your information that you will notice in Plate II, under the downtake a little reservoir *h*. We found, to our gratification, that cinders that were large enough to be so caught, come down into this reservoir and remain there. On the other hand, dust and smoke and very fine cinders pass along and up through the apertures and into the car. Indeed, when we had the twenty Globe ventilators and the maximum number appliances that I have described all open on going through the tunnel, the air of the car was so filled with smoke as to be quite suffocating.

In any system of ventilation it is absolutely essential that we should have control over it. Our scheme has been to have a valve in the downtakes; and possibly also valves connected with the ventilators, so that we could close them while passing through a tunnel, or when the wind happened to be in a direction to require it.

To our minds the problem of car ventilation stands now something like this. It is possible to get much more air into a car than any system now in use takes in. It is possible, if we could content ourselves with 20,000 to 30,000 or 40,000 cubic feet of air in severe weather to have such a ventilation system put on the cars to-day. Then in the milder weather we could increase it to the full capacity of the system. That phase of the question is being studied already quite earnestly. On the other hand, as everyone knows who knows anything about railroad matters, where there are 2,500 passenger cars requiring to be changed, it is simply ordinary business prudence to exhaust a subject pretty thoroughly and be sure of the ground before going ahead.

I am sure I am speaking the truth when I say that railroad officers appreciate the hardship of having to sit a number of hours in a badly ventilated coach as much as the public do. I can state, from my own knowledge, that they are thoroughly interested in this subject; and I am safe in saying that the intention is to prosecute it to a successful conclusion as soon as possible.

I thank you very much for your kind attention.

THE FRANKLIN INSTITUTE.

Stated Meeting, June 16, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH SPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA.

(Concluded from Vol. CXLIII, p. 424).

DISCUSSION.

MR. W. F. DURFEE, C.E. [Correspondence]:—The smoke nuisance is far from being a modern annoyance. About six hundred years ago, when the population of London did not exceed 50,000, its citizens petitioned King Edward I to prohibit the use of "sea coal," and he responded by making its consumption a capital offence. His successors, however, were more merciful to the users of coal, and its employment was resumed; but again, in the reign of Elizabeth, there were loud complaints against it, and, in 1661, John Evelyn, in his *Fumifugium,* laments that, "owing to the increase of coal smoke, the gardens no longer are fruitful." In the centuries that have followed there have been a number of parliamentary inquiries and some legislation intended to mitigate, if not remove, the evil, but, nevertheless, the consumption of bituminous coal has rapidly increased in London, and the inquiries and legislation relative to it have all ended—in smoke.

The nuisance of smoke in London is, as it has been for several hundred years, felt most severely during the prevalence of fog, and the vital statistics of that metropolis furnish abundant proof of the great evil of a smoke-contaminated atmosphere. We are told that "during the fogs of 1879-80, asthma increased 220 per cent. and bronchitis 331 per cent.;" and that "in the week ending February 13, 1882, the death rate, owing to the dense fogs, rose from 27·1 in the previous week to 35·3; diseases of the respiratory organs rising to 994, the corrected weekly average of this class of diseases being 430."

In discussing the smoke nuisance, which is so unpleasantly asserting itself as the manufacturing and commerce of the chief cities of our land augment, it is well in the outset to have a clear understanding of the objectionable elements of that exceedingly unpleasant and unsanitary fumid substance, which in English speech is called "smoke."

Smoke is the result of an imperfect combustion of carbonaceous substances, and always has, as an offensive, distinguishing component, more or less of solid carbon in a finely divided or flocculent condition (commonly called "soot"), associated with which are various gases and vapors, the character and volume of which depend upon the composition of the combustible employed and the degree of perfection attained in its burning.

In some coals we have present a notable amount of sulphur and hydrogen associated with their carbon; and the gaseous products of the imperfect combustion of such fuels would contain carbonic acid, carbonic oxide, sulphurous acid, sulphuric acid, the vapor of water, ammonia, nitrogen, carbureted hydrogen, and a modicum of other vapors and gases of less importance. All of these gases and vapors escape from the chamber in which the fuel is imperfectly burned, at a high temperature, up-bearing and spreading abroad the flocculent solid carbon or soot.

Most bituminous coals, when imperfectly burned, produce smoke of substantially the above composition, the elements of which are as variable as the conditions of temperature, and the "personal equation" of an unskilful fireman can make them. It is entirely unnecessary to prove that such smoke is injurious to health, or that it is destructive to vegetation, as these points are admitted by every candid investigator. What is demanded is a remedy for the existing evil. Fortunately that remedy is not doubtful, or difficult of acquisition. It consists simply in effecting the perfect combustion of the fuel used, and in the use of a fuel whose perfect combustion will not produce deleterious gases.

It will doubtless be asked: "Why, if the remedy is so simple, has it not been applied long ago? Why has London smoked and suffered for six hundred years, when a cure was at hand?" To answer this question is as difficult as to say why all men are not honest, when it is universally admitted that "honesty is the best policy." London is smoky because it fails to prevent the formation of smoke; and Paris is smokeless because it insists on a perfect combustion of its fuel. The remedy for the smoke nuisance is in the hands of the people who complain of its annoyance, and they have only to imitate the conditions existing in Paris, or any clean, smokeless city, to be rid of it forever.

It will doubtless be asked—what means have been successfully used in the past for the prevention of smoke? Answering this question in a general way, it may be said that all expedients for the prevention of smoke that have been effective have involved a regulated uniform supply of fuel in proportion to the requirements, and a regulated adequate supply of air to ensure its perfect combustion.

It would require much more time than is allotted to me to describe the various forms of apparatus that have been devised for carrying out practically the general principles of smoke prevention; but a brief reference to a few of the more prominent of these may not be without interest.

The first successful apparatus, of which we have any knowledge, that burned fuel without the production of smoke, was invented by Abu Musa Dschabir Ben Haiyan (better known by the name of Geber), an Arabian alchemist, who lived about the end of the eighth century. He is credited with the discovery of nitric and sulphuric acids, and of certain preparations of mercurial and other metallic salts. Geber called his furnace the Tower of Athanor, and from its construction a steady and uniform heat could be maintained for an indefinite period. Its principal feature was a high cylindrical tower for containing the fuel. This tower was flanked by two combustion chambers, in or over which the substance or vessel to be heated was placed. These chambers were connected with the central tower near its base, by flues, in which were dampers for regulating the flow of the gas generated from the fuel. This furnace of Geber was in fact a "gas furnace," and the general principles involved in its construction were the same as we see in every-day use in all self-feeding, base-burning stoves, and in many gas furnaces for metallurgical purposes; in fact, many of the so-called improved gas producers are no better and but slightly different from that invented by Geber over one thousand years ago, and he must be regarded as the discoverer of the great advantages resulting from converting solid fuel into a combustible gas, and then burning that gas in a combustion chamber separate from that containing the solid fuel. Geber's furnace was not a mere suggestion, but was in common use by chemists in all well-appointed laboratories, until the beginning of the present century.

In 1785 James Watt invented a method of smoke prevention, which is very simple, and in the hands of a careful fireman is very effective. I speak from personal knowledge, as I carried it out successfully in the burning of bituminous coal under a steam boiler thirty-eight years ago.

Various methods suggested have been patented, and some of them carried into successful practice, for preventing smoke by feeding the raw coal into the furnace beneath that already in a state of ignition. Other inventions contemplate the automatic supply of the solid fuel in a regulated constant manner; but from the time of Geber to the beginning of the present century no person suggested the employment of the ideas embraced in his invention, on a large scale in manufacturing operations, and the modern use of the waste gases from blast furnaces and refinery fires (which may be fairly regarded as gas producers) is believed to have originated with M. Aubertot, superintendent of the forges of Vierzon, in the Department of Cher, who obtained a French patent for it in 1807. His first apparatus was designed for the burning of lime or bricks and the cementation of steel.

The employment of the waste gases of blast furnaces was described by M. Berthier in 1814, but gas was not much used as a fuel until 1832.

The application of gas as a fuel for steam boilers was first made in 1832 or 1833, at a furnace in the Department of the

Mense, but it was not successfully employed until 1835, when MM. Dufournes, Thomas and Lourens solved this interesting problem in a satisfactory manner. In 1836, furnaces having boilers fired by gas were working with success at Neiderbrunn. In 1837 Wilhelm von Faber du Faur made successful experiments at Wasseralfingen, in Würtemberg, to burn the gases of blast furnaces in a reverberatory furnace, for the purpose of refining pig iron.

In 1839, M. Bunsen, of Cassel, devised an apparatus for collecting the waste gases of blast furnaces, for use under boilers. In 1840, Mr. Philip Taylor, of Marseilles, applied at a blast furnace at Rustel, in the Department of Vaucluse, the following-described construction: Gas was carried in a large cast-iron pipe from the upper part of the furnace to the boilers, which were placed at some distance from the furnace and was passed under the boilers through a number of slits, between which were other slits (regulated by a valve) for the admission of air. This is believed to be the first recorded instance of the employment of an arrangement which is now, with slight modification, in general use.

In 1845 Mr. James Palmer Budd obtained an English patent for the application of the heat, flames and gases of the blast furnace to the heating of hot-blast stoves, which was carried into practical operation at Ystalyfera Furnace, which was using anthracite coal. Mr. Budd calculated the annual saving in money, by this use of the gas, at £350; and so satisfied was he with his success in utilizing the waste gas, that (says Dr. Percy) he even ventured to draw the following conclusions: "It would seem to be more profitable to employ a blast furnace, if as a gas generator only, even if you smelted nothing in it, and carried off its heated vapors by flues to your boilers and stoves, than to employ a separate fire to each boiler and each stove. These considerations irresistibly suggest to me a great revolution in metallurgical practice—a new arrangement, in fact, of furnaces and works, by which considerably above £1,000,000 a year might be saved in the iron trade alone." This prediction of Mr. James Palmer Budd has been in no small measure realized by the invention of Mr. Frederic Siemens, who, in 1856, patented his well-known regenerative gas furnaces.

These furnaces have now been in use in this country over thirty years, and their excellent qualities are well known to all metallurgical engineers. These furnaces can consume, without the production of smoke, any solid substance that is used as a fuel, and many things that it would be impossible to use in other furnaces. Gas from Siemens' "producers" can be used under boilers with entire success, and the writer used such gas for boiler fires twenty-eight years ago.

In 1868, the writer hereof erected the first steel works in which gas was exclusively used as a fuel; in these works were two puddling furnaces, three heating furnaces, one 24-pot melting furnace, and ten gas producers. Gas from the producers was used to fire the boilers. The fuel employed was ¾ very fat bituminous coal, and ¼ anthracite coal dust. The waste products of combustion passed into the atmosphere through a chimney 100 feet high, having a flue 6 feet in diameter. There was no smoke discharged from this chimney, and although the works were in the immediate vicinity of residences and cultivated grounds, there was no complaint of smoke or noxious vapors of any kind.

Every one is familiar with the easy way of preventing a gas flame from smoking, and I am only speaking from my own practical experience, when I say that it is relatively just as easy to prevent fuel from emitting smoke.

The community that is a sufferer from the smoke nuisance, whenever it really resolves to put an end thereto, will find no difficulty in securing the services of engineers competent to devise and construct the proper apparatus for attaining that result.—WEST NEW BRIGHTON, STATEN ISLAND, N.Y., April 20, 1897.

MR. ARTHUR KITSON:—Whilst agreeing with most of the remarks made by the eminent gentlemen who have preceded me this evening, I must say that, in my judgment, the most injurious phase of the smoke nuisance has not yet been dealt with. It is the popular idea that the really detrimental and dangerous part of smoke, when inhaled, is the *visible* portion—

the particles of carbon that blacken the atmosphere—and it is believed that the cure for the nuisance is to render this carbon *invisible*, by burning it to carbonic acid gas. And the remedies that have been offered for its abatement to-night are confined to this popular notion.

Down-draft furnaces and mechanical stokers, invaluable as they may be, and undoubtedly are for many purposes, cannot rid us of the ammonia and sulphurous acid gases that constitute the worst feature of the evil we are here to discuss.

The statement, quoted by Mr. Outerbridge, that smoke is not really injurious to life—but, on the contrary, is healthful—created some amusement. What the writer evidently meant was that the inhaling of the *visible* constituents of smoke was not injurious; and this is attested by Dr. Littlejohn, of England, who recently reported on this subject to the Sheffield Board of Health. He says: "That black smoke in itself, as a thing breathed, is prejudicial to health, is even doubtful. Miners, who live in an atmosphere of carbon dust, are the next healthy class to farm laborers in the kingdom. When they die, their lung tissues are found of an inky blackness, but Hirt, a great authority on vital statistics, thinks it in the highest degree probable that coal dust (carbon) possesses the property of hindering the development of tuberculosis (consumption), and of arresting its progress."

Now, it is a well-known fact that the death rate in the smoky city of London is greatly increased during the months when fog is prevalent. In a fortnight of heavy smoke-fog, which prevailed in 1886, it is said that the rate of mortality rose from 16·6 to 40 per thousand. One authority asserts that an ordinary London smoke-fog kills from 170 to 200 persons per day in that metropolis.

What constitutes the fatal portion of the smoke-fog one may readily discover. In Paris, where fogs are frequent at certain periods of the year, the death rate is not so materially increased, and in Paris coke is the fuel generally in use. We have evidence sufficient to show that the visible part of smoke is not particularly fatal. The inference is sufficiently strong to warrant acceptance that the really dangerous elements of smoke are those invisible gases formed whenever soft coal is burned in an ordinary furnace or grate. Soft coal consists of carbon, hydrogen, sulphur, nitrogen and sometimes chlorine, with silica, iron, etc., forming the ash.

The burning of coal is really a chemical problem, and consists in the oxidation of the first three elements. If the supply of oxygen is ample, its distribution perfect, and the temperature of the elements sufficiently high, the products of combustion will be carbonic acid gas, steam and sulphurous and sulphuric acids. Part of the free nitrogen combines with the hydrogen and passes off as ammonia.

Unfortunately, however, the ordinary methods of burning coal will permit neither an ample supply of oxygen nor its proper distribution, and, in most cases, that portion of the coal requiring a high temperature is cool during its most critical condition. The result is, that instead of getting, as we should otherwise do, *invisible* products of combustion, we see clouds of black smoke—unconsumed carbon—emanating from our chimney stacks, blackening and disfiguring our buildings, hiding the sun's rays, and hanging like a pall over our cities. This is the really injurious feature of the visible portion of smoke. Whilst I believe carbon is the least harmful of the various ingredients which go to form smoke when inhaled, its physical effects in obliterating the sun's blue rays—which are essential to healthy vitality—are sufficient to warrant us in declaring war against the nuisance. Light is as essential to the well-being of animals as it is essential to plant life.

To some it may appear that I am giving undue prominence to the effects of the sulphur and nitrogenous and chlorine compounds, considering how small is the proportion of these to the principal matter constituting coal. It may, therefore, surprise those gentlemen to learn what amount is actually given off in localities where careful statistics are kept. "If the sulphurous acid alone which escapes into the air of Sheffield were deposited by rain within the area which gives it off," says a well-informed writer, "the ground would be washed every year with 1,000 tons of it per square mile." Another statistician informs us that the amount of ammonia annually sent off by the chimneys of London would, if properly treated, furnish over 700,000 tons of sulphate of ammonia. And here we have an illustration of a truth too often forgotten—that the law of healthfulness is the law of economy. The value of these waste products alone should be a sufficient inducement for us to seek some better system of combustion than that now prevailing. The value of this vast quantity of nitrogenous matter disfiguring and vitiating London's atmosphere exceeds that of all the fertilizers which England imports annually from Chili and Peru.

From what I have said, you may infer that I cannot regard the mechanical devices known as smoke consumers, mechanical stokers, down-draft furnaces, as offering the final solution of this problem. To reduce all of the carbon to carbonic acid before allowing it to reach the atmosphere, is indeed desirable, and one step—perhaps a long step—in the right direction. But these contrivances do not get rid of those other objectionable products.

The only proper solution I know of is the conversion of coal into gas, and its purification before distribution. Fuel gas, as it is called, meets every objection that can be raised against the burning of coal. It is scientifically correct. It is the only means for ensuring perfect combustion and avoiding the evils I have enumerated.

Remembering that combustion requires an intimate contact between the molecules of the combustible and the oxygen of the air, and that the more intimate the mixture and closer the contact the more nearly perfect the combustion, we can readily see how unscientific is the ordinary method of burning coal. The ordinary soft-coal furnace is a distilling apparatus, where soft coal is thrown upon a red-hot bed of fuel, and the valuable hydrocarbons and volatiles are distilled off and conducted unconsumed by a chimney to vitiate the atmosphere. Compared with this, the down-draft furnace, in which this volatile matter is made to pass through the fire and consumed, is entirely correct.

Before leaving this subject, it may be of interest to some members of the Institute to learn that a century and a quarter ago Benjamin Franklin was the greatest living authority on smoke prevention. He devised two or three different forms of smokeless grates, one of which he used during a three years' residence in London. The principle was the down-draft, and I believe he anticipated the celebrated James Watt in the invention of this form of furnace. The burning of lump coal is a gradual process; indeed, it may be truly said that coal cannot really be burned in lump. Its exterior surfaces begin to break into molecules; in fact, this molecular condition is essential for combustion. The inner portions of the coal, however, remain intact, and combustion cannot occur until all the exterior portions are burned away. In burning, however, the incombustible portions of the coal (silica, alumina, etc.,) remain as a deposit of ash, and serve to check the moleculization of the carbon underneath. For this reason a fire will often "go out" long before the carbon is consumed, the ash forming a sort of "insulator" to the contact of the air.

The smaller the coal the better the combustion, providing the air is brought properly in contact with it. Hence coal-dust burners have been used with great advantage as heating agents in securing better combustion. It is as gases, however, that molecular contact and intimate mixtures are obtained in practical perfection, and as this is the chemical theory of combustion, it follows that the conversion of coal to gas is the most reasonable method to adopt.

The gasification of coal is no longer an expensive process. It can be performed with a loss of not over 14 per cent. of the theoretical heat value of the coal, a loss which is considerably more than offset by the more nearly perfect combustion and greater efficiency of the gas. In other words, for almost all industrial purposes it would pay handsomely to convert the coal into gas, and use the gas for heat and power purposes rather than burn the coal directly. I have to-day a gas plant operating with hard culm from the Scranton culm piles, and am running a gas engine with this gas at the rate of 1¼ pounds of culm per horse-power. Culm is, as you know, a waste product of the coal mines, because of the difficulty of burning it. Yet, when converted into gas, it is more efficient for industrial purposes than are the better grades of coal if burned in solid form.

Let me say, in concluding, that I am not a believer in legislative methods of reform. The way to stop the smoke nuisance is to educate our manufacturers to understand that they are not only injuring the city and endangering the lives and happiness of thousands by their methods, but that they are also wasting thousands of dollars. Should the first plea fail to strike a responsive chord in their minds, the latter will be more likely to do so.

MR. WILLIAM M. BARR:—In metallurgical operations, the construction of a furnace for burning any kind of fuel is usually in charge of one who understands the principles of economic and smokeless combustion; it is to be expected, therefore, in the interests of trade, that such furnaces shall be efficient and economical, also that they shall, in the interests of good citizenship, be as nearly as possible smokeless in operation.

The problem which seriously confronts us in Philadelphia, by reason of its numerous, varied and non-centralized industries, is the possibility that steam boiler furnaces may, under the changing conditions of fuel supply, become public nuisances.

Most of the boiler settings in Philadelphia, especially those erected more than four or five years ago, have grates averaging not more than 24 inches below the under side of the boiler shell, and for anthracite coal this distance has been found to yield good results.

If these steam boilers are to continue in the use of anthracite coal no change need be made. In the case of bituminous coal, however, the problem is altogether different, because the combustion consists of two distinct processes.

When a furnace door is opened to receive a fresh charge of fuel, that act in itself lowers the temperature of the furnace by the admission of cold air over the fire, the fuel is cold and distributed over the whole surface of the grate, a distillation of the hydrocarbon gases immediately occurs in such pieces as are in contact with the incandescent fuel underneath, and this occasions a further lowering of temperature. Now, if the first product of this combustion be carbonic acid gas, which is probably true, it is certain that it is almost immediately changed into carbonic oxide gas during its passage through the burning fuel. The distillation of the volatile matter from the coal has, as just stated, the effect to lower the temperature of the furnace, and this favors the accumulation of minute sooty particles of carbon, which, being carried off by the other products of combustion, give color to the escaping gases at the top of the chimney. In the course of a few minutes the temperature is regained in the furnace; at the same time a less distillation of hydrocarbon gases occurs; as a result, better conditions of combustion are had, and in consequence less carbonic oxide gas and fewer particles of soot; in other words, less visible smoke.

The second stage is that of the combustion of the fixed carbon or the coke of the coal; this process is without smoke, the products being wholly transparent.

Hand-firing for small steam plants is likely to continue, and it is important, therefore, that the furnace be so constructed that if ordinary care be exercised the quantity of smoke emitted in any neighborhood may be less than that constituting a nuisance.

Bituminous coal should be broken in small pieces, the smaller the better, thinly and evenly spread over the fire; thick firing, especially if large lumps are thrown into the furnace, is not conducive either to economy or to smoke prevention.

Referring again to the distance of the grate bars from the boiler, my own judgment is that, for bituminous coal, the grate bars should not in any case be nearer than 40 inches to the boiler, if the coal is one likely to give off smoke. Some bituminous coals do not give off as much smoke as others, and steam boiler furnaces designed for localities where a comparatively smokeless coal will be continuously used, may have the grates 36 inches below the under side of the boiler. Some experiments have been made with grates 48 inches distant from the boiler where unusually smoky coals were used, and with excellent results. The explanation of this is easily had, and is probably nothing more nor less than the fact that bituminous coals require a roomy furnace for their perfect combustion, it being a common experience that roomy combustion chambers which favor the better admixture of air with the hydrocarbon gases and vapors distilled from the fire, give off less smoke than others.

To meet the local conditions of this city, my recommendation would be that, in all cases where a change is to be made within the city limits, in order that bituminous coals may be burned instead of anthracite, the boilers be reset, so that the space between the grate bars and the under side of the boiler should approximate 40 inches. The cost would not be great, and, with careful firing, would almost effectually prevent smoke.

For large steam plants automatic stokers may be used to good advantage, as automatic and continuous feeding is favorable to economy, as compared with ordinary hand-firing, while it also lessens the escape of smoke, because of a more thorough combustion. It matters little whether they operate upon a dead plate caking the coal, and afterwards burning the coke from which the gases have been distilled, or whether the coal be fed from underneath; either form, if properly cared for, will do good service.

The down-draft furnace has been very successful in smoke prevention, so also has the fore-and-aft system of firing, in which the products of combustion of one furnace, with its unconsumed gases and sooty particles, are made to pass over an incandescent body of fuel in another furnace, by alternately firing one grate and then the other. Changing the current of gases through the furnace to the chimney by means of dampers, however, involves a little extra labor on the part of the fireman.

Altogether, the solution of the problem is neither difficult nor impossible; it simply requires that the conditions be fully understood, and that the furnace be adapted to the required conditions, based upon a knowledge of the constituents of the fuel to be burnt. The subject is not a new one, and reliable experimental data are easily procurable for the guidance of all parties concerned, and the proper remedy can in each case be applied without working hardship to the owner of a steam plant, while relieving a neighborhood of what in time may become an intolerable nuisance.

DR. WM. H. FORD, President Board of Health, Philadelphia, Pa.:—I desire to say that the Board of Health feels very much gratified that the Franklin Institute has taken hold of the question of the smoke nuisance. This venerable Institute is particularly qualified for dealing with practical and scientific problems with which the municipality has oftentimes to grapple, and its suggestions received from time to time will enable the municipal government to deal more intelligently with questions involving the health and comfort of its citizens. On the other hand, it is interested in advancing industrial arts and in one hand, it is interested in advancing industrial arts and in legislation, and, on the other hand, it is interested in solving problems affecting the health of the community, the solution of which is based more or less upon a knowledge of scientific principles. Thus the Institute, in furnishing information on questions of great public interest, can be relied upon in giving judicious advice without prejudice to any interests involved.

The discussion this evening has been of a thoroughly practical character, and has developed points of great interest which must have a practical bearing upon the solution of this vexed question. Whether such a nuisance exists, or whether the production of smoke in large volumes by manufacturing establishments, locomotive stacks and the like, is a nuisance, hardly enters into the discussion, because the fact is self-evident and beyond dispute. Various cities, particularly those located in our Western country, where bituminous coal is almost the sole fuel used, have from time to time legislated on this subject, and some of the laws which have been passed are exceedingly stringent, perhaps more so than the circumstances demand. In our own city, until within recent years, there has been little annoyance from the production of smoke, for the reason that anthracite coal was almost entirely the fuel used in our factories and exclusively so in the household. But the development of the bituminous mines in the State has brought to our doors, at cheap prices, large quantities of soft coal, which is gradually supplanting the anthracite coal. The statements made here to-night show that the ratio of increase of consumption of bituminous coal is very much greater than that of anthracite coal, and this ratio, for various practical reasons, is destined to increase. The result is, that in certain localities in the city the smoke nuisance already exists to an extent that calls for some legislative regulation preventing the discharge of smoke, or, at least, restricting the practice.

There is, at the present time, before the Legislature a bill giving authority to cities in this Commonwealth to pass ordinances prohibiting the discharge of black, brown or gray smoke into the atmosphere. This proposed legislation originated on account of a doubt that has arisen as to the authority of City Councils to legislate upon this subject. The injury that smoke causes is seen in the household by its damaging effect upon fabrics, furnishings, in the begriming of the exteriors of buildings, and also in the discomfort which it causes when this smoke is produced in large quantities and in considerable density. There is no question as to the existence of a nuisance such as is described as "a nuisance at common law." The question whether the discharge of smoke into the atmosphere is injurious to the public health has been disputed by some, but from the evidence collected there can hardly be a reasonable doubt that there is from this cause a possibility of injury to health. The carbonic oxide and carbonic acid that are discharged into the atmosphere no doubt become speedily diluted, and it is not likely that they have any serious influence upon health; but the finely divided carbon and the sulphurous acid and tarry matters resulting from the imperfect combustion of soft coal, are undoubtedly agents active in their effect upon health.

It has been stated here this evening that the sulphurous acid, and perhaps the fine carbon particles, might be beneficial as an aërial disinfectant, but there certainly does not appear to be any evidence that the smoky air of towns is freer from the poisons of specific diseases than the air of other places. It seems to be a justifiable inference to assert that the finely divided carbon which constitutes smoke must have a mechanical influence upon the mucous passages, particularly of the lungs, and it may be that the sulphurous acid in the air may also prove irritating. It is said that persons visiting London, who are suffering from weak lungs, complain of the irritating effect of the air. Whether it can produce attacks of bronchitis and the like is not certainly determined, but it will scarcely be disputed that persons suffering from pulmonary disorders have their convalescence delayed thereby.

The question that mainly concerns us this evening is the possibility, or rather the practicability, of devising simple means of preventing the smoke nuisance, and such means as may be applied conveniently and without great expense. It appears from what has been said by the experts from different cities who have taken part in the discussion this evening, men who have practical knowledge of this subject in all its branches, that it is entirely feasible to introduce appliances by which the smoke can be consumed, thus preventing a nuisance and at the same time being somewhat advantageous to the establishments by economy in the use of coal. The mechanical stoker seems to have the preference, and as this apparatus has been used very largely in England with manifest advantage, and has been applied in many instances in our own country, and here in our own city in large establishments with great success, it is very evident that legislation prohibiting the production of colored smoke would not prove a hardship, and it is indisputable that such prohibition is required in the interests of the comfort of the citizens, if not for the protection of the public health. It has also been developed by this discussion that in many instances all that is necessary is careful, common-sense firing. This necessitates the careful selection of a fireman, his proper compensation, and the proper supervision of his work in order to require orders to be carried out with precision.

It may be said that Philadelphia, at the present time, is not a very smoky city, and why not wait until the nuisance exists before taking steps to correct the evil? To the judicious mind this does not seem to be the proper course of action. It is much wiser to prevent than to correct, and a regulation prohibiting the emission of colored smoke at the present time will not only correct the evil as it exists to-day, but will prevent the increase of an evil which is destined in time to cause very serious annoyance and loss of money by the deterioration of property, and possibly, in certain localities, by the injury of the public health. By all means, then, let the wiser course be pursued, which is, to take time by the forelock, and to prevent in the early stage what may hereafter become a nuisance assuming such proportions as to make it exceedingly difficult successfully to grapple with. The Board of Health places great confidence in the ability, wisdom and practical knowledge of the Franklin Institute, and for that reason has solicited its coöperation in securing the application of such measures as will compass this subject thoroughly, and overcome, without unnecessarily injuring the industrial establishments of the city, an evil which is already beginning to attract the attention of the people, who are anxious that measures be enforced for their protection.

MR. H. H. SUPLEE:—One of the principal causes of the production of smoke is the chilling of the fire and interruption to combustion due to the proximity of the comparatively cool boiler to the incandescent bed of fuel. The temperature of the fire is variously estimated at 2,500° to 2,800° F., while that of the boiler is usually below 350° F., and the result is a chilling of the gases and a precipitation of the carbon. This is well shown by holding a cold dish above a gas flame and observing the deposit of soot as soon as the flame is cooled.

This fact was well appreciated by James Watt, and his patent of 1785 contains as clear a description of the action and its remedy as has been made since. The furnaces shown in this patent and illustrated in Galloway's "History and Progress of the Steam Engine," London, 1830, show what is practically a gas-producer, a combustion chamber for perfecting the combustion before the gases reach the boiler, and what is practically the modern "down-draft" furnace. Watt says: "I cause the flame to pass through a very hot funnel, flue or oven, before it comes to the bottom of the boiler, by which means the smoke is more effectually consumed."

In recent times such furnaces have been constructed for burning wet tan-bark, sawdust and other inferior grades of fuel, and if the furnace and combustion chamber are properly proportioned, little or no smoke is produced. For large plants, however, it is undoubtedly advisable to burn the fuel in a separate gas-producer and deliver fuel gas to the boiler furnace, thus enabling the lowest grades of culm to be used without smoke. Ultimately, I have no doubt that it will be found far more economical to use producer gas in gas engines.

The question of oil fuel seems to be opposed mainly because of the inadequate supply; and in connection with that, attention may be called to the valuable paper of Chief Engineer Nabor Soliani, of the Italian Navy, read at the Marine Congress, at Chicago, in 1893, in which he shows that with proper care a good smokeless fire can be maintained with oil and coal used in combination, about one-fourth of the fuel being oil refuse and the remainder coal.

DR. COLEMAN SELLERS [Correspondence]:—Finding it impossible for me to be present at the meeting on the 19th inst., at which the discussion in regard to the "Smoke Nuisance and its regulation with special reference to the condition prevailing in Philadelphia" is to be continued, I would say that, personally, I can add but little to what has been so ably presented by those who attended the meeting of April 21st, or contributed by correspondence to the discussion, but the subject engaged my attention actively between the years 1847 and 1857, when residing in the city of Cincinnati, where the constantly increasing consumption of bituminous coal both in private houses and in factories added year by year to the discomfort caused by soot.

Legislation is necessary, but whatever is done in the direction of ordinances should be based upon what actually can be accomplished without serious loss or expense to those using smoke-producing fuel.

Residing in a part of Philadelphia where there are no factories burning bituminous coal, the smoke nuisance has proceeded mainly from the locomotives in the yards of the near-by railroads. That the nuisance can be abated in locomotives by judicious firing, needs no further proof than that afforded by the correspondence of Mr. Edward Longstreth and Mr. Samuel M. Vauclain. Both of them show what part the fireman himself plays in the management of the fires so as to make the combustion as nearly perfect as possible with the least smoke.

I would suggest that inquiry be made into the condition that obtains in regard to the starting of a fire with bituminous coal in the yards of the railroad companies, as the number of engines that must be prepared and made ready for the trains necessitates the frequent re-starting of fires; hence if care be not exercised at these points the residents of the city in the neighborhood must necessarily be more or less incommoded.

I have noticed in the city of London that the starting of fires in the afternoon at the great electric light stations has been accompanied with such enormous volumes of black smoke as to give to the neighborhood the appearance of an immense conflagration, and this at the time of the year when London is most free from smoke. At the time that I noticed this effect, mechanical stokers were not employed, and the great discharge of smoke, though coming from very high chimneys, was confined chiefly to the period of starting the fires and was less apparent afterwards.

The information that has already been laid before the Institute by those who have contributed to this discussion seems to me sufficient to show that it is possible to burn smoke-producing fuels to much better advantage than is done in common practice, hence the need of an ordinance that can be enforced, by an earnest effort on the part of law-abiding citizens in the spirit of justice. The information laid before the Institute should be gone over carefully by the committee which the Institute has appointed for the purpose, and the ordinances that have been passed in various cities for the abatement of the smoke nuisance should also be considered in reference to the action that should ultimately be recommended to the Mayor and the Councils of the city of Philadelphia, as practicable and likely to be beneficial.

Electric light and power stations depending upon coal can be operated without any excessive discharge of smoke into the air, and probably without inflicting any hardship upon the companies engaged in this work. I think, however, that attention should be given to the gain that would accrue from the use of water-power that is within easy reach of Philadelphia, and the introduction of electricity created by the water-power, as supplementing what can be obtained from coal.

It has only been within a very few years that the judicious employment of water-power transmitted to users by electricity has been possible, and what has now been done in this and other countries shows the enormous importance of the utilization of what has been placed at our disposal by nature in the streams within reach. Legislation is needed to enable these water-powers to be so used. Such legislation has been sought, but has been met by the strong opposition of those who consider the fishing interests of paramount importance and liable to be wholly destroyed by power-development schemes. I think, however, that the danger has been very much exaggerated and too little attention paid to the real advantages that will accrue to the city of Philadelphia by the fostering of these power schemes with due attention to all other interests involved. Users of power are awakening to the knowledge that the mode of transmitting power by shafting and other mechanical contrivances is wasteful in the extreme, as compared to what can be accomplished by electricity. I think, therefore, that it would be well if some of the earnest thought of those interested in the abatement of the smoke nuisance were turned also in the direction above indicated.

MR. WM. A. INGHAM [Correspondence]:—There is no smoke nuisance in Philadelphia. Our clear skies prove that.

London, Pittsburgh and Chicago have a smoke nuisance, and I think all this recent movement here is what I would express mathematically as an equation of the second degree. That is, the above-named cities have a real smoke nuisance, therefore Philadelphia has the right to have one. If not, she will be behind the age.

I have looked south and east and north and west from the Bullitt and Bourse Restaurants. I have counted the steam discharges (every one representing a steam engine run by coal) and have also counted the chimneys emitting smoke. Within that horizon there is not one in fifty engines which emits black smoke. This does not include the Kensington iron mills nor the sugar refineries.

Smoke in moderate quantities is not a *nuisance*. Here I must discriminate: (*a*) A nuisance is whatever injures or annoys. (*b*) A nuisance is whatever is injurious to health, though it may not be perceptible to the senses.

(*a*) Excessive black smoke, as in London, Pittsburgh and Chicago, smuts and dirties linen and furniture.

Aside from smut and dirt, is smoke unwholesome? If not, there is no reason for the Board of Health to intervene.

(*b*) Now, I do not hesitate to say that a moderate amount of smoke in our atmosphere not only is not unhealthful, but acts as a purifier.

Smoke, besides unburnt carbon, which is hygienically inert, contains sulphur, which is a well-known disinfectant.

I *believe* the malaria in the Juniata Valley has materially diminished since the Pennsylvania Railroad Company has been saturating the atmosphere with smoke from its engines. But I cannot *prove* this, as I have no statistics.

If smoke is a nuisance anywhere, which is certainly not the case at present in Philadelphia, then it is perfectly easy to consume all smoke under stationary boilers, which constitute the great majority of coal users.

I say it is perfectly easy to do this. There are twenty (possibly fifty) efficient devices to consume smoke. The only question for the consumers is, will it pay?

While I admit that a person who burns his smoke, instead of wasting unconsumed carbon at the top of his chimney stack, will make some saving in fuel, I am not prepared to say that even with the best appliances available at present it will be economical for him to burn his smoke.

And this is probably the reason why these devices have not been universally adopted. They do save what was unconsumed carbon. But they cost so much to install and operate, that the balance of saving is on the other side.

To sum up:

(1) There is no *smoke nuisance* at present in Philadelphia, as is shown by our clear skies.

(2) The small amount of smoke emitted from our chimneys may, *perhaps*, be a benefit rather than an injury.

(3) It is perfectly practicable to consume smoke in stationary boilers.

As to locomotives, that is another story. It can be done, however, though at considerable cost and some loss of power. The best way, in my opinion, for locomotives, is to avoid *generating* smoke by using smokeless fuel, anthracite, coke or smokeless soft coal.

Mr. Washington Jones [Correspondence]:—Any discussion of the alternatives of "smoke or no smoke," or, in other words, the perfect or imperfect combustion of bituminous fuels, in large quantities, to me seems like "threshing old straw;" for the numerous, carefully-made experiments(and the published reports thereon) by competent chemists and engineers, are conclusive, and, if not known, should be known by all who are interested as steam users, too many of whom are so indifferent to the material saving that may be effected by firing properly, that they neglect to have instructions given to their firemen, when and how to replenish the fires.

I will venture, in this paper, to give a few extracts from authorities on the subject: In "The Economy of Fuel," by T. Symes Prideaux (Weale's Series, London, 1853), paragraph 10, will be found the following: "It is commonly but erroneously supposed, that when no smoke appears at the chimney top, combustion is perfect. Smoke, however, may be absent, and yet the carbon may have united with only 1 atom of oxygen, forming carbonic oxide (a colorless gas), instead of with 2 atoms, forming carbonic acid, and consequently have performed only half the duty, as fuel, of which it was capable, whilst the loss of duty on the coal taken as a whole (supposing all its hydrogen to have become oxidized), will be upwards of 40 per cent." Again, in the concluding words of paragraph 13: "A furnace, immediately after a fresh supply of fuel, requires more than double the quantity of air it did the instant before, whilst we have no contrivance for furnishing such a supply, although without it, throughout the space of time during which rapid gasification of the hydrogenous portion is going on, more than half the fuel consumed is wasted, and passes off unburnt, becoming thereby not only totally unproductive in itself, but absolutely an agent of evil, by robbing the furnace of the heat absorbed in its own volatilization."

In the *Journal* of the Franklin Institute, (third series, Vol. XXXV), will be found an article copied from the (London) *Mechanic's Magazine,* containing the report of a commission consisting of Messrs. Longridge, Armstrong and Richardson, appointed by the Steam Colliers' Association, of Newcastle-upon-Tyne, to determine the value of Northumberland coal compared with that mined in Wales, which submitted the following: "On the Use of Steam Coals, etc., in Marine Boilers." They say, in paragraph 1: "That the coal from your district, commonly called the 'Hartley's" may be consumed in ordinary multitubular marine boilers without making any smoke. (2) That this may be done without the adoption of any of the various schemes which have been brought before us. (3) That it does not involve any loss of power or economy; but that with a given boiler *more* water may be evaporated, whilst no smoke is made, than can be evaporated with the hardest firing on the usual system accompanied by a dense smoke; and further, that the economic effect, or the quantity of water evaporated by 1 pound of coal, is greater when no smoke is being made, to the extent of from 17 to 22 per cent."

It is to be regretted that the report does not define the phrase "usual system;" but, it may be assumed to mean—thick fires and closed furnace doors—as the final report (see (London) *Mechanic's Magazine,* Vol. 68) describes several systems submitted to the commission for preventing the formation of smoke. One of these, commended by the commission, is that of C. Wye Williams, C. E., whose well-known "Treatise on the Combustion of Coal and the Prevention of Smoke" is exhaustive. The plan of Mr. Williams is to admit above the fire, atmospheric air through a number of small holes in front, and at the sides of the furnace. This plan has been used successfully by the writer in many cases, but somewhat modified by heating the air by causing it to pass through the ash-pit into a hollow bridge wall in which a course of bricks near its top and next to the combustion chamber were laid in pairs, on edge, about ¼ of an inch apart, without cement between them, thus forming several apertures of ¼ x 2½ inches, through which the air emerges and mixes with the gases. The admission of air to the chambered bridge-wall was controlled by a damper in the ash-pit.

All the authorities agree in this dictum: After a fresh supply of fuel is put upon the grates, air *must* be admitted above them and its volume regulated by a damper.

Mr. Robert Wilson, C.E., inspector for the Manchester Steam Users' Association, in his "Treatise on Steam Boilers," remarks on page 254: "In burning semi-bituminous steam coals a considerable quantity of fresh air is required for combining with the hydrocarbons above the layer of coal, and must be admitted directly to the gases at the furnace front, or at the bridge, or which is perhaps better, at both. Whichever plan is adopted, too great care cannot be taken to admit the air in small jets by perforations, or other means, especially when its direction is parallel with the current of gases. This ensures a better mixing, and prevents to a very material degree the undesirable cooling effect of introducing a large volume of cold air in one place, which is liable to defeat the end for which it is introduced."

Much depends on the fireman. No "hard and fast" rule can be applied to the manner in which he should manage his fires, but he must learn from experience the working peculiarities of the grates, flues, stack, etc., and adapt his methods to them.

Thomas Box, in his "Practical Treatise on Heat," says in paragraph 111: "It will also be seen in every case the proper regulation of the damper is a matter of extreme importance, and that nice adjustment is necessary to produce the best effect, too much or too little air causing a great loss of fuel; an intelligent stoker (fireman), without any knowledge of the theory, finds by experience the height of damper with which he can do the work with the least fuel; if the work varies he watches and adjusts the damper accordingly, and such a man should have more consideration and better wages than he usually receives."

Perhaps the most effective way to abate the smoke nuisance will be, not by legislative enactment, imposing a penalty, as in the towns of Great Britain, but to convince users of bituminous coal who permit smoke to appear at their chimney tops that it is an unmistakable evidence of wasteful firing, for which the remedy is in their own hands. Frequent, moderate replenishment of coal, evenly spread over thin fires already glowing, and a sufficiency of fresh air admitted to the furnace above the fires, will prevent the evil. The resulting material reduction in the amount of the coal bills will prove to be a most convincing argument, and the emission of smoke from stacks will be an evil of a past era.

PROF. H. W. SPANGLER:—Many furnaces are run in a very uneconomical way, and in many places where smoke-consumers, so-called, have been introduced, the efficiency of the combination has been largely increased. It is perfectly safe to say that in all such cases, even without the use of smoke-consumers, the efficiency might have been largely increased.

The value of smoke-consumers, as such, to the owner of a plant kept in proper shape is practically nothing. That is, a furnace hand-fired, having a large fire surface, with the coal properly coked before being pushed over the fire, will emit large quantities of smoke when the coal is green. The value of this smoke, if it could all be entirely burned, has been shown to be less than 2 per cent. of the heating value of the coal. That is, practically, the smoke is valueless to the owner of the plant.

In many cases when boilers are inefficiently run, the self-interest of the owners will make it easily possible to prevent the formation of smoke by persuading them or forcing them to put in such apparatus as will, for their sakes, make their plants more economical, and for ours, do away with the smoke.

In those cases where, because of insufficient furnace area, very large quantities of coal must be burned per square foot of grate surface to develop the power of the boiler, no device, short of rebuilding the boiler, will reduce appreciably the formation of smoke, and in many cases where attendants are apparently at fault, closer examination will show that the apparatus for burning the coal—the furnace, as distinct from the boiler which absorbs the heat—is at fault.

This question is as old as the burning of soft coal; it has been investigated by all sorts of commissions and the technical papers are filled with descriptions of devices for doing this particular work. All these have resulted in little towards correcting the evil, because it is cheaper not to bother about the smoke. When these devices have been used it is because they are supposed to be heat savers, not smoke preventers.

Nevertheless, the black soot is a nuisance; the major portion can be prevented in many existing stationary plants, and new plants can be erected so that the future annoyance from this cause can be reduced to a minimum.

In the case of locomotives the story is quite different, and probably the only feasible method of practically doing away with the smoke is to stop using soft coal, although care in firing will probably reduce the quantity greatly. Even if this were done the annoyance would by no means be over. The distance to the top of the smoke-stack is so small that the products of combustion, which will always carry dirt and coal particles with them, will annoy persons living along the line of the railroads. The odor of the hot products of combustion from anthracite is almost as unpleasant as are those from soft coal. Steps should be taken to insure that all locomotives constantly in use in the city should be practically smokeless.

No attempt should be made to prevent the using of soft coal, and as each case needs separate treatment, judicious advice will, in many cases, accomplish all that is desired. When new plants are to be installed, or old ones extended, for the use of soft coal, the plans should be approved by the proper official before they are built. Sufficient time should be allowed before any compulsion is attempted.

MR. A. FALKENAU:—One of the main objections urged to firing so as to give smokeless products of combustion, is the danger of loss of heating effect by the use of too great an excess of air. It is, therefore, desirable to mark the point where the combustion is most nearly perfect; that is, where neither smoke is produced nor an unnecessary amount of heated air passed up the chimney.

The Arndt econometer, an instrument for continuously recording the percentage of carbonic acid in the escaping flue gases, is used to some extent in Europe with apparently very satisfactory results. It appears that in some cases where the instrument was applied, the amount of carbonic acid indicated was only 4 to 5 per cent. In these cases the alteration of the grates and furnaces brought the percentage up to 12 or 14.

With such an instrument in use the control of the furnace becomes much simplified, and the point at which the smoke just disappears could easily be recorded. The instrument is simple in construction, being practically a pair of scales, having an inverted glass bell on one arm and counterweight on the other. The flue gases flow continuously in and out from the inverted jar, and any variation in density is at once read from a pointer traversing a scale, graduated so as to indicate the percentages of carbonic acid up to the theoretical 21 per cent.

If instruments for registering the conditions of combustion had received the same attention and development as those used in the control of steam, it is likely that the satisfactory solution of the smoke question would be much nearer realization. If furnaces and flues were regularly equipped with water gauges, pyrometers and econometers, a more intelligent class of firemen would soon be created.

MR. F. LYNWOOD GARRISON:—When fresh bituminous coal is thrown upon a hot fire a destructive distillation takes place, resembling somewhat that which is effected in heating such fuel in a retort when making coal gas for illuminating purposes. In other words, its volatile constituents are driven off. These consist essentially of certain combustible gases, the moisture and the sulphur compounds. The latter two constituents are extremely variable, and their consideration is not necessarily essential to this discussion. It is the volatile combustible gases which give us trouble and are the essential cause of smoke; that is, the black, objectionable smoke. The amount of these volatile gases in the coal varies, as a general average, from 12 to 30 per cent. They consist of marsh gas (CH_4), ethylene (C_2H_4), some acetylene (C_2H_2), benzol and other hydrocarbons, together with variable quantities of carbon monoxide (CO). Now even under the worst possible conditions some of these gases will be consumed, and only a portion will be available for the purpose of producing smoke. The most competent investigators have found under fairly good conditions that a very small amount of heat is lost even when a large proportion of these gases escape unburnt, which is especially noteworty as individually and collectively their calorific power is great. Scheurer-Kestner found, even when a thick black smoke was produced by limiting the air supply, that the loss of heating effect due to the smoke amounted to only 1½ per cent. and an increase of air reduced this ½ per cent.*

It is evident that there is no notable economy to be gained in consuming the smoke, and that the cost of the appliances necessary to effect its consumption would more than offset the increase in heat thereby derived.

There are two reactions by which the formation of smoke may be explained. It is probable they take place simultaneously in most cases, and individually under certain conditions. Where the fire is very hot, the affinity between the hydrogen and carbon decreases; thus when ethylene (C_2H_4) is passed over a highly heated surface, a portion of the carbon (black smoke or lampblack) is deposited and a new gaseous hydrocarbon is formed. Then again it would seem that under other or perhaps similar circumstances, marsh gas (CH_4) reduces CO_2 with the separation of carbon (black smoke).

Deville showed by the following experiment how hydrocarbon gases were dissociated by sudden cooling. A curved copper tube was introduced into the gaseous current just behind the fire bridge, both ends of the tube projecting outward. When the tube was empty it soon attained the temperature of the gases at that point; if filled, however, with water allowed to circulate so as to keep it cool, it quickly became

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coated with soot produced by the dissociation of the gases. Precisely the same thing takes place when we hold a cold plate in the ordinary illuminating gas flame. Likewise, everyone has noticed at the top of a chimney, that the escaping gases often leave a clear space for a few inches, then burst into a yellowish flame which, as it arises and comes further into contact with the cold atmospheric air, turns into black smoke.

The question before us is how to avoid this smoke by burning the furnace gases before they can become dissociated. It is plain, that smoke is either the result of an insufficient air supply, or an excess thereof at too low a temperature.

The effectual means of preventing the formation of this objectionable black smoke are limited to two classes of appliances. A third might, perhaps, be included in the indirect, though, perhaps, most effectual, system of converting the carbon of the coal into gas, the volatile carbon into the combustible gases I have mentioned, and the fixed carbon or coke into water gas by means of steam; the gases thus generated being burnt under the boilers or used directly to generate power in gas engines.

The first system to avoid smoke is to supply the fuel and air in regular and constant quantities by mechanical firing or automatic stoking. This method is fairly effectual, and of late years has been much improved. Its economy, from a business view, is, however, quite another matter, and is determined by a variety of conditions.

The second system is to promote so thorough, quick and intimate a mixture of the gases and air as to produce complete combustion. This is often effected by the use of a steam jet, which, while doubtless effective in some cases, is certainly the means of a great loss of heat.

When a furnace is hand-fired, the fresh fuel, added intermittently, requires more than double the amount of air it did the moment before; here the air supply must also be intermittent, since an excess of air is as bad as an insufficiency; that is, the fluctuations of the air supply must be made to coincide with those of the fuel. It would seem that these conditions can only be met by very skilled firemen, and even then the results leave much to be desired in the ordinary run of boilers, etc. The prevention or absence of smoke does not necessarily prove perfect combustion of the fuel. It is sometimes possible to prevent smoke by greatly limiting the supply of air, in which case a large portion of the potential of the coal may ascend the chimney in the form of highly combustible and invisible CO, entailing an enormous loss of heat.

MR. JAY M. WHITHAM [Correspondence]:—The proper method of preventing smoke is not to form it. Smoke-consumers *per se* do not exist. Smoke is formed from a volatile coal during the period of coking, and because either enough air for thorough combustion is wanting as the gases are distilled, or because this air is not properly diffused, or because the temperatures are unfavorable for combustion.

From a commercial standpoint, smoke, though unsightly and annoying in many ways, is no great loss in combustion, seldom exceeding one-third of 1 per centum of the fuel burned. When conditions favorable to the formation of smoke exist, the efficiency of the furnace is generally low, and a more or less serious commercial loss takes place, due to the non-combustion of invisible gases. Conversely, when the conditions are favorable for burning the invisible gases distilled from the coal, smoke formation takes place only in a slight degree.

To get good combustion, and hence not to form smoke, it is important to secure:

(1) A grate with from 40 to 70 per cent. of air openings.

(2) A draft strong enough to produce an active combustion, *i. e.*, not a smothered fire.

(3) A high furnace temperature.

(4) A roomy furnace, so that the gases may *linger* and have *time* for burning before traversing much of the heating (*i. e.*, refrigerating) surface of a boiler.

(5) To feed the fuel either regularly, as with a mechanical stoker, or lightly and at short intervals by hand-firing.

(6) To thoroughly understand the fuel to be burned, since the treatment most favorable for burning Cumberland coal will not be best suited to Reynoldsville coal, etc.

It is not necessary to expend a large sum in installation in order to burn fuel with but trifling smoke formation. In hand-firing ordinary furnaces and ordinary boilers, but little smoke will be formed if the furnace be coaled lightly, through alternate doors. In this way but a part of the fire is covered at one time and the gases and air are heated by the remainder. The fire should not be sliced or broken up until the coking is effected. Openings in the front of the furnace, varying with the rate of combustion from ½ to 2 square inches per square foot of grate area, are a decided advantage, while but little gain results by the use of a split bridge.

In horizontal tubular boiler settings no special advantage results from the use of a refractory coking arch over the front of the grate, but its presence is desirable for a volatile coal burned under a water tubular boiler. When such an arch is used, of course the coal should be coked in front and then spread, the fires being from 10 inches to 14 inches thick in front, and from 4 inches to 8 inches thick behind.

The period of smoke formation need never be long when using mechanical stokers, if they are properly handled, and have sufficient area for the work required. Such devices are, however, costly in installation and also in repairs (the repairs per year often amounting to from $5 to $10 per square foot of grate, while the first cost is from $25 to $40 per square foot).

The Hawley Down-Draft Furnace is now being introduced in Philadelphia, and has been in operation elsewhere for years. I have made a number of careful tests of it, varying from ten to 132 hours. For thirty-four hours, observers, with stop watches, found that the smoke record was about as follows:

Stack clear	93	per cent. of the time
Faint gray color	4	" " " " "
Dark gray color	2	" " " " "
Black	1	" " " " "

Such a record means smokelessness. The furnace is high, while the stack gases are low in temperature. The combustion chamber is always incandescent, and the stack gases are practically devoid of unburned constituents, as shown by repeated analyses.

This furnace possesses all of the essentials for smokelessness and good economy and does not require special skill in operation, but is expensive in installation, and may not be suited to all kinds of feed waters.

MR. W. M. STEIN [Correspondence]:—The pollution of air and water constitutes a serious problem in densely populated manufacturing districts; and the solution of this problem offers a wide field of investigation to the engineering and chemical professions. The question of the smoke nuisance is a very old and difficult one to handle, and numerous inventions have been patented in various countries to abate the same or reduce it to a minimum. Ordinances have been passed in all civilized countries against the smoke nuisance. A great fault of all ordinances which I have studied is that they are pointed exclusively against smoke from manufacturing establishments. Smoke arising from residences and small industrial establishments is, as a rule, not covered by the laws, and for this reason the laws are more or less insufficient or even unjust.

The aim of all large consumers of fuel is to avoid needless waste and the smoke usually connected therewith. Most modern works have availed themselves of apparatus giving the desired economy and practical smokelessness at the same time. Large furnaces can now be economically operated by any of the well-known systems of gas-firing. For large boiler plants, gas-firing is practicable, or automatic stokers may be used, provided that they are well designed. Well-prepared fuel of uniform size is necessary to obtain good results with automatic stokers.

On the continent of Europe several systems of coal-dust firing have been introduced with successful results. The fuel used is finely pulverized (80 meshes per inch), and this fine powder is ingeniously introduced into the fire-place. Practically, the theoretical amount of air required for complete combustion is admitted. The better systems of coal-dust firing are absolutely smokeless. The dust firing is already successfully employed for puddling, heating and crucible melting furnaces, as well as for boilers.

The city of Berlin uses a number of dust-firing apparatus in connection with some of the municipal boilers. As a whole, there can be no doubt that large consumers of fuel can arrange their plants economically and smokeless. For locomotive firing in the city limits it would be advisable to use anthracite or coke as much as possible.

To abate the nuisance of smoke arising from domestic fireplaces and small industrial establishments is a much more difficult than from large establishments. As a rule, the fireplaces in dwellings and small industrial establishments are much less economical, and necessarily cause proportionately much more smoke.

Fortunately our city is so located that anthracite coal and coke can be had by the small consumer at reasonable prices. The smoke from these sources can be reduced to a minimum. Cheap fuel gas can be supplied to small consumers in cities located in the soft coal district, and the present state of the science of gas-making is such as to guarantee cheap gas for the future.

Personally, I am opposed to legislation for the regulation of the smoke nuisance, as it would be very difficult to pass laws to cover the subject perfectly without causing injury to many. I believe the question will solve itself through the necessity of economy.

DR. W. H. FORD:—I do not wish to occupy time which may be turned to better advantage, but I would like to say that the discussion which has occupied two evenings has been thorough, comprehensive and conclusive. The results obtained have been definite, and indicate first, that the smoke nuisance exists to a considerable extent, although it is not so excessive as it might be, and as it will most certainly become in the course of time, unless some measures are introduced for its restriction. In the second place, it has been demonstrated, very satisfactorily, that the smoke nuisance is entirely unnecessary, as there are means of its prevention easily procured or adopted without entailing any hardship or great expense upon the owners of boilers. In the third place. it has been shown that by proper ordinances, requiring the application of apparatus and the proper management of firing, the smoke nuisance may be measurably controlled, if not entirely prevented.

It is much easier and much wiser to suppress this nuisance now, before it has become so very general, than to wait until it has grown to such proportions that any regulation aimed at its suppression will necessarily require an immense amount of reconstruction, and provoke formidable opposition.

The decision of the Institute to collect and print the valuable data presented at this discussion, which has been participated in by experts from different parts of the country, and by men who have practical knowledge of mechanical engineering, will be of great advantage in consummating the object for which these meetings have been called, namely, to suggest and endorse a reasonable plan for suppressing the smoke nuisance. The collected data and arguments—always useful for reference—together with the support of the Franklin Institute, will go far toward furthering the efforts that are being made by the authorities and citizens in removing from our fair city a nuisance which is not only annoying, but, in many cases, positively detrimental to the public health.

THE PRESIDENT requested Mr. Outerbridge to close the discussion.

MR. OUTERBRIDGE:—Owing to the lateness of the hour, I will omit the experimental demonstration I had prepared for the purpose of showing how great a smoke a small amount of bituminous coal may produce, and how easy it is to thoroughly consume this smoke when suitable conditions are provided therefor.

It is not at all surprising to me that the gentleman from Reading (Mr. Sternbergh), who spoke this evening, found that the introduction of "a large quantity of air" above his fire failed to consume the smoke. Excess of air (which contains 77 per cent. of inert nitrogen) is worse than useless; for smoke has a flashing point, just as petroleum has a flashing point, but a much higher temperature is requisite to cause smoke to burst into flame.

In order to successfully consume smoke, it is necessary that the air with which it comes in contact should be, at all times, heated up to the point, which I have ventured to call "the flashing point," of smoke. An excess of air over the required amount is wasteful of heat.

A familiar and simple illustration of the flashing point of smoke is afforded in the case of a match-stick or other small piece of wood held above the chimney of an Argand burner. The heat causes the wood to char, the smoke rises with the current of hot air and gases, and, being heated up to the flashing point of finely divided carbon, takes fire and burns several inches above the wood.

Soft coal differs from anthracite, mainly in the fact that it carries from 25 to 35 per cent. of "volatile matter," consisting of hydrocarbon and other gases, which pass off invisibly, when the coal is heated to a moderate degree, and of carbon in fine particles, which escape in the visible form of smoke or soot. The weight of the smoke is comparatively trifling, and its fuel value is therefore small, but the presence of smoke is the visible evidence of imperfect combustion of the more valuable invisible gases.

The necessity of frequently opening the furnace doors, when soft coal is fed by hand, is largely responsible for the production of smoke, because the in-rush of cold air reduces the temperature in the flame chamber temporarily below the flashing point—or combustion point—of finely divided carbon. The smoke is therefore carried out unconsumed and discharged into the atmosphere, thus often creating a smoke nuisance.

There are, as we know, quite a number of mechanical appliances which have been devised for the automatic feeding of coal to stationary boilers and for effecting the complete combustion of smoke. Some of these appliances are simple in design others more complicated; some will burn any kind of cheap bituminous slack without visible smoke appearing at the chimney top, others will not do so under all conditions.

Now that the principles of smokeless combustion of bituminous coal are so well understood and are capable of application to all stationary boilers, there is surely no reason for the encouragement of the growth of a smoke nuisance in this city by failure to provide suitable restrictions or regulations. For these reasons I think it is clearly within the domain of this Institute to record its sentiments in favor of some practicable legislation, and I have therefore prepared a few resolutions which I will present for your consideration:

WHEREAS, The Board of Health of the city of Philadelphia has requested the Franklin Institute to investigate the question of smoke prevention and to offer practical suggestions relative thereto; and

WHEREAS, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and

WHEREAS, It appears from testimony of scientists and expert mechanics, presented at this meeting, by invitation of this Institute, that it is practicable to burn bituminous coal in stationary boilers and furnaces without creating a smoke nuisance;

Therefore be it Resolved, That it is the sense of this meeting that the continuous or frequent discharge of dense black smoke from the combustion of bituminous coal is unnecessary and should not be permitted within the city limits.

Resolved, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health and to the Presidents of City Councils.

After some discussion, the foregoing preamble and resolutions were referred to the Board of Managers, with the request to report to the next stated meeting of the Institute on the propriety of their adoption.

APPENDIX.

As a matter of general interest bearing on the subject of the foregoing discussion and for convenience of reference, there is hereto appended copies of the municipal ordinances for the regulation of the smoke nuisance, now in force in a number of cities of the United States. W.

SMOKE ORDINANCES.

CHICAGO, ILL.

SECTION 1650. The emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney anywhere within the city, shall be deemed and is hereby declared to be a public nuisance, provided that chimneys of buildings used exclusively for private residences shall not be deemed within the provisions of this ordinance.

SEC. 1651. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise, in the working of the engine or engines in said boat or in operating such locomotive, and the proprietor, lessee or occupant of any building who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building within the corporate limits, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined in a sum not less than $5 nor more than $50.

SEC. 1652. It shall be the duty of the Commissioner of Health and the Superintendent of Police to cause Sections 1650 and 1651 of this article to be enforced, and to make complaint against and cause to be prosecuted all persons violating the same.

CINCINNATI, O.

SECTION 1. Be it ordained by the Board of Legislature of the city of Cincinnati, that the emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney anywhere within the city, shall be deemed and is hereby declared to be a public nuisance; *provided* that chimneys of buildings used exclusively for private residences shall not be considered within the provisions of this ordinance.

SEC. 2. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise in the working of the engine or engines in said boat, or in operating such locomotives, and the proprietor, lessee or occupant of any building who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building within the corporate limits, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined in a sum not less than $5 or more than $50.

SEC. 3. It shall be the duty of the Supervising Engineer to cause the enforcement of this ordinance, and to make complaint against and cause to be prosecuted all persons violating the same; and in so doing he shall be assisted by the Superintendent of Police and the Health Officer, and their respective departments.

SEC. 5. This ordinance shall take effect and be in force from and after the earliest period allowed by law.

CLEVELAND, O.

SECTION 1. Be it ordained by the Council of the city of Cleveland that the emission of dense smoke from any chimney anywhere in the city, or from the smoke-stack of any boat, locomotive or stationary engine or boiler within the limits of the city of Cleveland shall be deemed and is hereby declared to be a public nuisance.

SEC. 2. That the emission into the air of any noxious gases or vapors or offensive odors from any manufactory, building or premises within the limits of said city, injurious to health or annoying to the inhabitants of said city, or any part thereof, shall be deemed and is hereby declared to be a public nuisance.

SEC. 3. That the owner, lessee, engineer, fireman, or other person or employé having charge or control of, or operating any boat, locomotive or stationary engine, or boiler, manufactory, building or premises, within the corporate limits of said city, who shall permit or cause dense smoke to issue from any smoke-stack or chimney thereof, or connected therewith; or any owner, lessee, or other person or employé having charge or control of, or operating any building, manufactory, building or premises within the said corporate limits, who shall cause or permit any noxious gases or vapors, or offensive odors, as described in Section 2 of this ordinance, to issue from such manufactory, building or premises shall be deemed and held guilty of creating a public nuisance, and upon conviction thereof in the police court of said city, shall be fined not less than $50, nor more than $100 for each and every such offense.

SEC. 4. That it shall be the duty of the Health Officer of the Department of Police to enforce the provisions of this ordinance, and he shall, upon his own motion, or upon the complaint or information of any resident of said city, commence proceedings in the police court against any person for violating any of its provisions, whenever, in the judgment of said Health Officer, facts warrant such proceedings.

SEC. 5. That the words "owner," "lessee" and "person" occurring in this ordinance in the singular number shall include the plural; and they shall each be construed so as to embrace corporations, or partnership associations, as well as natural persons.

SEC. 6. That this ordinance shall take effect and be in force from and after its passage and legal publication.

PITTSBURGH, PA.

An ordinance to regulate and suppress the production and emission of smoke from bituminous coal; and to provide penalties for the violation thereof in certain districts of the city.

SECTION 1. *Be it ordained and enacted by the City of Pittsburgh;* That from and after September 1, 1892, the emission of smoke from bituminous coal, or escape of such smoke from any chimney or smoke stack used in connection with stationary boilers within the limits of the following defined district: Beginning at Miltenberger Street and Second Avenue; thence along the northern curb of Second Avenue to the eastern line of the city; thence along said city line to the Allegheny Valley Railroad; thence along the Allegheny Valley Railroad to the Sharpsburg Bridge; thence along Bridge Street to Butler Street; thence along the southern curb of Butler Street to Penn Avenue; thence along the south curb of Penn Avenue to Thirty-third Street; thence along Thirty-third Street to Center Avenue; thence by Center Avenue to Devilliers Street; thence by Devilliers Street to Dinwiddie Street; thence by Dinwiddie Street to Fifth Avenue; thence by Fifth Avenue to Miltenberger Street; thence by Miltenberger Street to Second Avenue, at the place of beginning, shall be deemed and is hereby declared to be a public nuisance.

SEC. 2. That it shall be unlawful for any corporation, co-partnership or individual owning, controlling or using any chimney or smoke-stack used in connection with stationary boilers within the limits of the district, as provided in Section 1, to allow, suffer or permit smoke from bituminous coal to be emitted or escape therefrom.

SEC. 3. Any corporation, co-partnership or individual who shall or may allow, suffer or permit smoke from bituminous coal to be emitted or to escape from any chimney or smoke-stack used in connection with stationary boilers within the limits of the district, as provided in Section 1 as aforesaid, shall, in addition to any and all law requiring the abatement of nuisances, forfeit and pay to the city of Pittsburg for every such offense a sum not less than $10 or more than $50, to be recovered before any Alderman of the county of Allegheny, or any Police Magistrate of the city of Pittsburg as debts of like amounts are now recoverable.

SEC. 4. No discrimination shall be made against any device or method which may be used which will accomplish the purpose of this ordinance in relation to the said matter.

SEC. 5. The Chief of the Department of Public Works of the city of Pittsburgh is hereby empowered to enforce the provisions of this ordinance.

OHIO STATE ORDINANCE.

An Act to Provide for the better Protection of Human Life against Fire, and Regulate the Construction and Management of Steam-Boiler Furnaces in Cities of the First and Second Grades of the First Class.

SECTION 4. Every steam-boiler furnace used within the corporate limits of any city of the first grade of the first class shall be so constructed or altered, or have attached thereto such sufficient smoke preventives as to produce the most perfect combustion of fuel or other material from which smoke results, and so as to prevent the production and emission of smoke therefrom so far as the same is possible. And any person, or persons, association or corporation, being the owner or lessee, or having control of any such steam-boiler furnace (who) shall use or allow the use of any such steam-boiler furnace which shall not be so constructed, or if already constructed at the time of the passage of this act, shall not be so altered, or shall not have attached thereto such efficient smoke preventives as to produce the most perfect combustion of fuel or other material from which smoke results, and so as to prevent the production and emission of all smoke therefrom so far as the same is possible, or shall fail to keep such steam-boiler furnace for the prevention of smoke, and such smoke preventives in good and efficient order and operation, shall be subject to a fine of not less than $20 nor more than $50 for the first offense, and for each subsequent offense shall be fined not less than $50 nor more than $100. And no steam-boiler furnace shall hereafter be constructed in any city of the first grade of the first class, except in accordance with the requirements of this section, under the penalty of $50 for each offense.

SEC. 5. Every person having charge of the igniting, making, stoking. feeding or attending any such furnace and any smoke preventives attached thereto in good and efficient order and use, shall see that the least possible smoke shall be produced and emitted therefrom, and any such person who shall fail or neglect to so ignite, make, stoke, feed or attend such furnace fire that the least possible smoke shall be produced or emitted therefrom, or shall fail or neglect to keep such furnace or smoke preventives attached thereto in good and efficient order and use, or shall hinder or disarrange any such furnace or smoke preventives attached thereto, shall be subject to the payment of a penalty of not less than $20 nor more than $50 for the first offense, and not less than $50 nor more than $100 for each subsequent offense.

SEC. 6. The mayor of the city in every city of the first grade of the first class shall appoint a person of suitable qualifications as Supervising Engineer, who shall hold his office for the term of two years. from and after the date of his appointment, and until his successor is appointed and qualified; and he shall have authority to supervise and require all steam-boiler furnaces in such city of the first grade of the first class to be constructed, or if already constructed, to be so altered or have attached thereto such efficient smoke preventives, so as to produce the most perfect combustion of the fuel or other material from which smoke results, and so as to prevent the production and emission of all smoke therefrom so far as the same is possible, and he shall further have authority to supervise the igniting, making, stoking, feeding and attending such steam-boiler furnace fires; and he shall have further authority in the performance of the duties of his office, to enter any steam-boiler or engine room, or any building not occupied exclusively as a private residence, and any person or persons hindering or obstructing him in the performance of such duties shall be subject to a fine of not less than $20 nor more than $50, or imprisoned in the workhouse for a period not exceeding thirty days.

SEC. 9. The penalty for any violation of the provisions of this act, not otherwise specially provided for, shall be not less than $20 nor more than $50 for the first offense, and not less than $50 nor more than $100 for each subsequent offense.

SEC. 10. All acts or parts of acts inconsistent or in conflict with this act, be and the same are hereby repealed.

SEC. 11. This act shall go into effect and be in force from and after its passage.

ST. LOUIS, MO.

An ordinance declaring the emission of dense black or thick gray smoke to be a nuisance, and to provide for the suppression thereof.

Be it ordained by the Municipal Assembly of the City of St. Louis, as follows:

SECTION 1. The emission into the open air of dense black or thick gray smoke within the corporate limits of the city of St. Louis, is hereby declared to be a nuisance. The owners, occupants, managers or agents of any establishment, locomotives or premises from which dense black or thick gray smoke is emitted or discharged, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall pay a fine of not less than $10 nor more than $50. And each and every day wherein such smoke shall be emitted shall constitute a separate offense.

SEC. 2. This ordinance shall take effect at the expiration of six months after its approval by the Mayor.

Approved February 17, 1893.

An ordinance authorizing and providing for the making of regulations limiting and defining permissible smoke emissions, and for the testing of smoke-prevention devices, and for the making of such tests and experiments as may be deemed advisable with a view to the abatement or suppression of the smoke nuisance.

Be it ordained by the Municipal Assembly of the City of St. Louis, as follows:

SECTION 1. The President of the Board of Public Improvements is hereby authorized and directed to appoint, with the approval of the Mayor, a commission composed of three competent persons, who shall not be directly or indirectly interested in the manufacture, sale or construction of any furnace or other article having practical relation to the production or prevention of smoke. Said commission shall ascertain by a thorough canvass of the city and report to the Board of Public Improvements within four months after their appointment, the conditions and liabilities under which manufacturing and other parties cannot wholly or reasonably prevent the occasional production and emission of dense visible smoke. Such ascertained conditions and liabilities, when approved by the Board of Public Improvements and Mayor, shall be published, and thereafter shall constitute instructions to guide and limit the officials charged with the enforcement of smoke supression ordinances. And it shall be a valid and sufficient defense against any complaint that the offense charged comes within such recognized conditions and liabilities.

Said commission shall conduct and make practical tests of all devices for the prevention or suppression of smoke which shall be submitted to them, in accordance with the conditions hereinafter set forth, and shall prepare detailed reports, stating the facts and conclusions based thereon, as to the efficiency of such device, the conditions of its successful operation and the limitations to its efficiency. Said report shall be made promptly when any test is completed, to the Board of Public Improvements, which report may be rejected by said Board if found to be unfair or untrue. If accepted by said Board, the report shall be published for the information of the public.

Said commission shall also be called upon by the President of the Board of Public Improvements to make such tests and experiments as may, in his judgment, be needed to determine the applicability of special or smokeless fuels to domestic, locomotive or other uses, with a view to the abatement or suppression of smoke, and shall prepare detailed reports of the results, together with such conclusions and recommendations as in their judgment may be warranted by the facts, said reports to be made promptly and printed for the information of the public.

SEC. 2. The commissioners authorized by the preceding section shall receive, in compensation for their services in ascertaining, by a thorough canvass of the city, and reporting the conditions and liabilities of smoke suppression, the sum of $1,000 each, payable upon the certificate of the President of the Board of Public Improvements that such report has been made to and accepted by the Board of Public Improvements. For their services in conducting tests of devices and making reports thereon, they shall each receive the sum of $75 for each device tested and reported, and for conducting the special tests and experiments, as provided in the preceding section, $100 for each series of tests or experiments, together with a full report of the same. Said respective sums to be paid on the certificate of the President of the Board of Public Improvements, that the report of such test has been received and accepted by said Board.

Incidental and other necessary expenses for the above-described investigations shall be allowed and paid for as other expenses of the President of the Board of Public Improvements.

SEC. 3. Any party having, or claiming to have, a plan or device whereby smoke can be prevented or suppressed, and desiring to have the same subjected to a practical test and determination, may do so on the following conditions

(1) He or they shall notify, in writing, the President of the Board of Public

Improvements, that such a test is desired, and with such notice shall file a full and complete description of the device, with all necessary drawings to show its character, construction and mode of operation. Accompanying such notice shall be a certificate of the City Treasurer that there has been deposited with him to the account of the fund for testing smoke-prevention devices the sum of $400, and said sum of $400 shall absolutely become the property of the city of St. Louis, and no claim shall hereafter be made or allowed to refund the same or any part thereof; and upon the presentation of the Treasurer's certificate to that effect, the President of the Board of Public Improvements shall order the commission to make the test.

(2) The party or parties submitting a device shall erect the same at such place as the commission may approve, at their own cost and expense, under their own supervision, with such provisions for the attachment of instruments as the commission may require, and when fully ready shall deliver the premises and equipment to the commission.

(3) If, after test is begun, alterations or improvements are desired to be made, the party interested must proceed as if submitting a new plan or device, unless the several commissioners shall each consent to such alterations and waive all claim for compensation for a partial test.

Sec. 4. Whenever the Mayor shall be of the opinion that the public interest does not warrant the further testing and reporting on devices, under the authority of the ctty of St. Louis, he shall notify the President of the Board of Public Improvements to that effect, in which event the existence of the commission, hereby authorized, shall terminate when tests already in hand shall have been completed and reported as herein provided.

Sec. 5. When the commission created by the preceding sections of this ordinance shall have made its report as provided in Section 1, and shall have found that there are practicable methods of appliances by which the emission of black or thick gray smoke may be prevented, and such report shall have been approved as hereinbefore provided; and, also, when an ordinance declaring the emission of black or thick gray smoke to be a nuisance and to provide for the suppression thereof, shall have come into full force and effect, then the President of the Board of Public Improvements is hereby authorized and directed to appoint, with the approval of the Mayor, such inspectors, not exceeding three in number, as may be necessary to carry out the provisions of the following section of this ordinance. Said inspectors shall receive a salary of $100 a month each, payable monthly.

Sec. 6. The inspectors shall have a right to enter, in the performance of their duties, at reasonable hours, upon all premises other than dwelling houses occupied by less than four families or tenants. They shall collect evidence of the facts in the case of the violation of this ordinance, declaring the emission of black or thick gray smoke to be a nuisance and to provide for the suppression thereof, and, with the approval of the President of the Board of Improvements, shall report the same to the City Attorney for prosecution. The inspectors shall be guided in the performance of their duties by instructions given by the Board of Public Improvements from time to time.

Approved February 17, 1863.

DETROIT, MICH.

REVISED ORDINANCES, CITY OF DETROIT, 1895.

Chapter xc. Prevention of Smoke Nuisance, Approved June 8, 1887.

SECTION 1. The emission from any chimney or smoke-stack within the city, of dense smoke, or smoke containing soot or other substance in sufficient quantity to permit the deposit of such soot or other substance on any surface within the corporate limits of the city, shall be deemed, and is hereby declared, a public nuisance.

SEC. 2. Any owner, agent, lessee, or manager of any building, boat, locomotive or other structure in the city of Detroit, who shall cause or permit dense smoke, or smoke containing soot or other substance as above, to be emitted from such structure, or from any other place which said soot or other substance shall damage the property or injure the health of any person, or shall especially annoy the public, shall, on the complaint of any person so damaged or injured, as aforesaid, or on complaint of any citizen or officer of the city, in case of especial annoyance, be liable for each and every such offense to a fine of not less than $10 nor more than $100, or to imprisonment in the House of Correction not less than ten days nor more than thirty days, or both such fine, or imprisonment in the discretion of the Court: *Provided*, That the provisions of this ordinance shall not apply to buildings used exclusively for private residences or to steamboats.

MILWAUKEE, WIS.

An ordinance to prohibit the emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney within the limits of the city of Milwaukee.

The Mayor and Common Council of the City of Milwaukee, do ordain as follows:

SECTION 1. The emission of dense smoke from the smoke-stack of any boat or locomotive, or smoke-stack anywhere within the limits of the city of Milwaukee, shall, from and after the date when the provisions of this section shall take effect, be deemed and is hereby declared to be a nuisance, provided that chimneys of buildings used exclusively for private residences shall not be deemed within the provisions of this ordinance.

SEC. 2. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise in the working of the engine or engines in said boat, or in operating such locomotive, and the owner, lessee, or occupant of any building who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any chimney or smoke-stack within the said limits shall be deemed guilty of creating a nuisance, and shall, for every such offense, be fined not less than $5 nor more than $50, or punished by imprisonment in the House of Correction for not more than sixty days. Every day which said nuisance shall continue shall be deemed a separate offense.

SEC. 3. Hereafter before approving plans and specifications for the erection of any business building or factory within the limits aforesaid, it shall be the duty of the inspector of buildings of the city of Milwaukee to see that proper provision is made in said plans and specifications to prevent the emission of dense smoke from the chimney of said building.

SEC. 4. It shall be the duty of the Commissioner of Health and the Chief of Police to cause Section 2 of this ordinance to be enforced, and to cause complaint to be made against all persons violating the same.

SEC. 5. This ordinance shall take effect and be in force from and after the first day of January, A.D. 1898, except that the provisions of Section 3, thereof shall be in force from and after its publication.

Passed February 3, 1896.

PHILADELPHIA, PA.

Copy of ordinance submitted to Councils January 1, 1894. (Never acted on.)

An ordinance to prohibit the firing or running of locomotive engines or the firing of stationary or portable boilers emitting dense smoke, the result of imperfect combustion of soft or bituminous coal, within the city limits, and to declare same a public nuisance.

SECTION 1. The Select and Common Councils of the City of Philadelphia do ordain: That the firing or running of locomotive engines, or the firing of stationary or portable boilers emitting dense smoke, the result of imperfect combustion of soft or bituminous coal, anywhere within the incorporated city, shall be deemed and is hereby declared a public nuisance.

SEC. 2. The owner or owners of any locomotive engine, or stationary or portable boiler, and the person or persons employed as engineer or otherwise in operating such locomotive or stationary or portable boiler, who shall permit and allow dense smoke, resulting from the imperfect combustion of soft or bituminous coal therein, to issue or be emitted from the smoke-stack of any such locomotive or stationary or portable boiler, within the corporate limits, shall be deemed and held guilty of creating a public nuisance, and shall for each such offense be liable to a penalty of $50, to be recovered in the manner that penalties for breach of ordinance are now by law recoverable.

SEC. 3. It shall be the duty of the Director of the Department of Public Safety to enforce the provisions of the ordinance, and to make complaint and and cause to be prosecuted all persons violating the same.

This ordinance shall take effect and be in force from and after January 1, 1894.

MINNEAPOLIS, MINN.

Amending an ordinance entitled "An ordinance declaring the emission of dense smoke within the City of Minneapolis a public nuisance, and prohibiting the same," approved February 16, 1894.

The City Council of the City of Minneapolis do ordain as follows:

SECTION 1. That an ordinance entitled "An ordinance declaring the emission of dense smoke within the City of Minneppolis a public nuisance and prohibiting the same, approved February 16, 1894, be and the same is hereby amended so as to read as follows:

SEC. 1. The emission of dense smoke from the smoke-stack of any locomotive or engine, or from the smoke-stack of any stationary engine, or from the smoke-stack or chimney of any building anywhere within the City of

Minneapolis shall be deemed, and is hereby declared to be a public nuisance and is hereby prohibited.

SEC. 2. The owner or owners of any locomotive engine and the general manager, superintendent, yard-master or other officer of any railroad company having charge or control of the operation of any locomotive engine, and the person or persons employed as engineer or fireman in operating such locomotive engine, who shall cause, permit or allow dense smoke to issue or be be emitted from the smoke-stack of any such locomotive engine within the City of Minneapolis, shall be deemed and held guilty of creating a public nuisance, and of violating the provisions of this ordinance.

SEC. 3. The owner, lessee or occupant of any building, and the fireman, engineer, or any other person having charge or control of any furnace or stationary engine who shall cause, permit, or allow dense smoke to issue or be emitted from the smoke-stack or chimney connected with any such furnace or stationary engine within the city of Minneapolis, shall be deemed and held guilty of creating a public nuisance and of violating the provisions of this ordinance.

SEC. 4. Any person or persons violating the provisions of this ordinance shall, upon conviction thereof before the Municipal Court of said city, for every such offense, be punished by a fine of not exceeding $100, and may be imprisoned until such fine is paid, not exceeding ninety days.

SEC. 5. It shall be the duty of the Commissioner of Health and Superintendent of Police to cause this ordinance to be enforced and to cause to be prosecuted all persons violating the same.

SEC. 2. This ordinance shall take effect and be in force from and after its publication.

Passed September 25, 1895.

MECHANICAL AND ENGINEERING PROGRESS AS INFLUENCED BY THE MINING INDUSTRY. *

By JOHN BIRKINBINE.

The Franklin Institute was organized seventy-three years ago, 'for the promotion of the mechanic arts," and advances in this direction have carried its members into all branches of applied science.

The appropriateness of an active section of the Institute devoted to discussing problems in geology, mineralogy, mining and metallurgy becomes evident when we consider the influences upon mechanical progress and upon all branches of engineering which the development of the mining and metallurgical industries has exerted.

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*Opening address at the organization meeting of the Mining and Metallurgical Section of the Franklin Institute, April 28, 1897.

The railroad would be little more than a suggestion for economical transportation without the possibility of substantial rails, bridges, cars or locomotives. The production of these and the tools used in their creation are in turn dependent upon the metallurgical processes which transform ores, fuels and fluxes into metal of commercial shapes, and the development of these processes has encouraged exploitations of mineral deposits in such manner and of such magnitude as to supply satisfactory raw materials at low cost—a result which has been attained by intelligent investigation on the part of geologists and mining engineers.

The railroad is merely used as an illustration, for similar statements could be introduced to suggest the primary dependence of all, or nearly all, of our industrial and commercial advancement, and many of our modern comforts, upon the geologist, the mineralogist, or the mining and metallurgical engineers.

Travellers passing through a section of this or any other siastic at the number of imposing mills and factories, and point siactic at the number of imposing mills and factories. and point with satisfaction to these evidences of development; and if a train is scheduled to arrive at an industrial center, when crowds of well-dressed artisans are going to or returning from their daily labor, the appreciation of the value of these industries to the workingman and to the State is emphasized. But journeys through mining districts, as a rule, offer fewer evidences of great achievements; for beyond the head and power-houses or the "breakers" of mines, stocks of mine timber, rows of miners' cottages, and, in some cases, great piles of mine refuse, there is little on the surface to indicate what is being accomplished; and it is only occasionally that the mine openings are located near enough together to permit of any considerable concentration of working forces. Even if the miners are seen *en route* to or from work, the division of labor into "shifts" of from eight to twelve hours each, and the necessity of lifting the miners in small companies from below the surface, usually prevent any large assemblage of workmen. There are exceptional mining localities where a number of shafts are close together, and hundreds of men and boys may be seen at one time, but even in these instances the grime of the underground life has a tendency to detract from the effect upon the general observer.

As visitors enter shops or mills, the clatter of machinery and the rapid movement of workmen, or the glare of furnaces at manufacturing industries, is more impressive than the puffing of hoisting engines, the throb of pumps, the rumble of the tram at mines, or the smothered reverberation following a blast below ground. The flame and sparks belching from converters at a Bessemer steel works, and the movement of ladles, hot ingots, shifting engines, etc., give to the casual observer an idea of activity beyond that represented by a mine of great magnitude, and yet a mine of moderate size may give employment to as many men as a large iron or steel works.

Thousands of miners toiling deep in the earth's strata are not only lost to sight, but generally entirely forgotten by the public, until an Avondale fire, a Twin Shaft cave, or an explosion, sacrifices such a number of lives as to appall the community and direct attention to the work of the human mole.

If we fail in an appreciation of the extent of the mining industry we are equally at fault in recognizing the influence which it exerts upon our development. The utilization of 150,000,000 to 175,000,000 long tons of coal, annually won from American mines, for industrial and household purposes, may, perhaps, be approximately gauged; or we may measure the advance in wealth due to the exploitation of the minerals each year to produce 55,000,000 to 60,000,000 ounces of silver, 2,000,000 to 2,250,000 ounces of gold, 350,000,000 to 400,000,000 pounds of copper, 170,000 short tons of lead, 90,000 short tons of zinc, quicksilver to the amount of 36,000 flasks, more than 500,000 to 1,000,000 pounds of aluminium, 53,000,000 barrels of petroleum, 8,000,000 to 9,000,000 barrels of cement, 11,500,000 to 13,500,000 barrels of salt, clays valued at $10,000,000, $35,000,000 worth of building stone, $13,000,000 worth of natural gas, 12,000,000 to 14,000,000 pounds of borax, 15,000,000 to 16,000,000 tons of iron ore, etc. But even this impressive array of figures does not convey a just idea of conditions, and few truly realize what has been and what is being done by the mining industry to advance our nation.

To assist in forming a conception of the progress for which the engineering profession and the mechanic arts are indebted to this industry, attention may be directed briefly to some of the achievements which may be justly credited to the underground exploitation of our mineral resources.

Mr. Eliot Lord, in his monograph, "Comstock Mining and Miners," writing of that section of the State of Nevada which has produced gold and silver to the value of $380,000,000, says: "Such is the nature of the region bordering upon the eastern slope of the Sierras, and such the character of its savage inhabitants, that forty years ago no territory in America seemed more unlikely to attract a swarm of colonists. Except along its northern boundary, there was nothing to tempt the entrance of the intrepid fur trader, and even the undaunted Jesuit missionaries contented themselves with maintaining the white crosses of their stations on its border line. Thus the outside world knew and cared to know but little of this broad and seemingly worthless tract, and the homes of the Basin tribes would have been secure from intrusion to this day had it not been for the discovery of the treasures hoarded up in the barren ridges and cañons. The train of emigrants which crossed the plains in the year 1849 had no eyes to see the possible riches of the land through which they were passing, for their faces were set steadfastly toward the glittering beacon beyond the Sierras."

The Comstock lode is selected as an illustration, because its development rapidly transformed a desert mountain region, distant from any settlement, into a populous business center, supplied with superb evidences of engineering skill. The character of the ore won was the inspiration which developed some of the best forms of crushing appliances; the depth of workings, the size of deposits, the quantity of water to contend with, and the extreme heat of the lower workings demanded the construction of superior hoisting, ventilating and pumping machinery; the "square set" system of timbering (without which many other deposits could not now be successfully exploited), the construction of a drainage tunnel which is world-famous, and other innovations, resulted from the developments on the Comstock lode. The demand for timber to sustain the underground workings encouraged the application of the water-flume 25 miles long as a means of transportation, and the necessity of a supply of potable water was met by the construction of one of the earlier pipe lines conveying water under enormous heads, for which the Western country is famous. It is stated that, to supply the timber used in the Comstock mine, 200,000 acres of woodland have been cut over.

The migration in 1849, of seekers for gold, opened up the wealth of California, and that State is entitled to credit for many advances in hydraulic engineering devised to maintain its mining industry. Immense dams, long and tortuous canals or flumes, the cutting away of great masses of earth by streams of water delivered through "Little Giants" under heavy pressure, the diversion of streams, so as to work their natural beds as placers, and the construction of impact water wheels, operating under heads of water which previously had been considered impractical, are some of the results of mine developments. Colorado may well share in this credit, for it has extensive mining tunnels, elaborate water-power installations, etc., but in that State the construction of railroads in deep cañons or over high mountain passes, to reach the mines and convey their output to market, is probably considered the most notable feature. Montana, Oregon, Arizona, Utah, and in fact the entire mountain and Pacific sections of our great West, present numerous instances of progress, due primarily to the development of mineral properties, and the mining industry is undoubtedly largely responsible for the early completion of our transcontinental railroads.

The exploitation of iron and copper ores of the Lake Superior region has been a most potent factor in the material advancement of that district, and in the development of the lake marine. The depth of these mines, the quantity of material handled, and the distance from points of consumption and from fuel supplies, have inspired the mechanical engineer to design hoisting, pumping and concentration plants second to none, and the marine engineer to supply vessels of superior construction and equipment.

The "New South" also owes its present advanced position more to the exploitation of its mineral wealth than to any other feature.

Coming nearer home, we may properly ascribe the construction of the canal system and the earlier railroads to the necessity of conveying the output of our coal mines to market, and of handling economically in large volume raw materials to, and the products from, furnaces and mills, and the pre-eminence of Pennsylvania as an industrial State is directly traceable to the utilization of its stores of fuels, ores, stones and clays.

It is unnecessary to multiply illustrations of the influences which the development of mines has exerted upon the progress of the country, or to point to the many instances where the geologist, the mineral explorer or the mining engineer have been pioneers in opening up sections of our country which, without their energy and investigation, would have remained practically a *terra incognita* for decades. Nor are such illustrations confined to our own country, but of the world over the same story may be told.

Mr. George F. Kunz, in an interesting lecture before this Institute, lately detailed the story of the momentous results in the world's history, and the territorial changes, which were directly traceable to the discoveries of and the search for precious stones and metals, and he could have drawn similar conclusions from the efforts to operate or control the sources of the useful minerals.

The exploiting of mines, therefore, has not only called into play the ability and energy of the geologist and the mining engineer, but has demanded also the best efforts of the metallurgist, the mechanical engineer, the electrical engineer, the civil engineer and marine engineer, to supply drilling, hoisting, ventilating, pumping and beneficiating machinery, or appliances for handling and transporting the product by land or water; and has called on the chemist for the analyses of minerals, metals or gases and for the production of explosives. These specialists have been able to accomplish the desired results by placing the execution of their plans in the hands of intelligent mechanics, and to such artisans we are indebted for many of the mechanisms which to-day make cheap mine handling and transportation possible, and which permit of transforming the materials won from the earth into forms applicable to general use.

It is only when one descends into mines and notes the great chambers dug out of the earth, the quantities of timber placed to support, as far as is possible, the weight of roof or hanging wall, the massive pumps which elevate enormous volumes of water from great depths, and the powerful hoisting and ventilating appliances, that the magnitude of the mining industry is appreciated. When he investigates further and notes the drills penetrating the hard rock, or the cutters channeling below the mass, or locomotives traversing the low, narrow drifts, operated by electricity or compressed air, generated at some distant point, the aid of the mechanic becomes apparent.

The dip compass, the prospecting drill, the sinking pump, the steam winch, the rock drills, the crushers, the coal cutters, the chutes and the tram cars; the framing of shafts, mine timber, head houses and breakers; the conveyance of steam, water, air or electricity for power in hoisting, tramming, pumping, etc.; the rails, locomotives, cars and loading bins; the shipping and receiving docks for coal and ore, and the vessels built for their transportation; the machinery of concentrators, breakers, the buddle rocker, the vanner, jig and stamps, etc.; the blast furnaces, converters and roll trains, with their motive powers, all represent developments in the mechanic arts. Therefore, the discussion of modes of occurrence of minerals, of methods of mining and processes of manufacture, which will form part of the transactions of this section, must result in "the promotion of the mechanic arts."

The influence of the mining industry can be demonstrated to have extended into all branches of the mechanic arts; and in an organization devoted to the advancement of these arts there is a special and extended field to be covered by a Section devoted to geology, mineralogy, mining and metallurgy. As president of this Institute, I am gratified that the Section starts with such a flattering expression of interest, and can promise hearty co-operation in its work.

CHEMICAL SECTION.

Stated Meeting, Tuesday, May 18, 1897.

Dr. Jos. W. Richards, President, in the chair.

NOTES ON LUCIUM.

By Waldron Shapleigh.

In May of last year I secured several samples of the so-called "lucium" which had been prepared by Dr. Leon Schützenberger, of Paris, and at the same time saw a report in which this chemist gave very fully the methods which he used in preparing it, and his conclusions regarding the same; also samples of the monazite sand used.

The methods he employed follow very closely those set forth in the patent of Mr. P. Barrière.

The monazite sand was a low-grade North Carolina sand, containing minerals rich in titanium, zirconium and yttrite earths, such as menaccanite, rutile, zircon crystals, samarskite, euxenite and xenotime, and it is probable that from the last three minerals the "lucium" is obtained.

On experimenting with a solution of the lucium nitrate, the ignited ash or residue I found to be of a dirty gray color, and nearly entirely soluble in hydrochloric and nitric acids even when diluted. This solution was clear and pink, and gave the absorption bands of erbium. As the time recommended by Mr. Barrière for digesting with the potassium sulphate for the separation of the cerite group seemed to me rather short, I saturated the solution with potassium sulphate in the cold and allowed it to stand forty-eight hours, thereby obtaining a precipitate consisting of the cerite group, and in the solution, the yttrite group. Analysis showed:

Yttrite group oxides	93·98
Lanthanum, cerium, didymium oxides	3·74
Thorium oxide	1·07
Titanium, zirconium, potassium, sodium oxides, and sulphuric acid, not separated	1·21
	100·00

The oxides of the yttrite group after this thorough purification by potassium sulphate were of a light buff or yellow color, fully and completely soluble in dilute acids. Sodium hyposulphite did not give a precipitation in a fairly concentrated solution, nor was there any difficulty in making a partial separation of the erbium nitrate in the fused nitrates by Bahr and Bunsen's method. Although the quantity at my disposal was small, I obtained the erbium nitrate crystals and showed the possibility of this separation.

Regarding the precipitation with sodium hyposulphite, on which great stress is laid as a reaction, showing "lucium" to be a new element, if a solution of yttrite sulphates in a concentrated solution of potassium sulphate made by cold digestion is heated, a copious precipitation will ensue. Though not a perfect separation, yet advantage can be taken of this reaction in separating yttrium from erbium, and this reaction should be borne in mind when separating the cerite from the yttrite group, as some text-books recommend using hot saturated solutions. By doing so, some of the yttrium will be precipitated with the cerite group.

This action of heat on the double sulphate solution of the yttrite group, if it does form similar salts to the cerite group, I have not met with in the text-books. Therefore, inasmuch as Mr. Schützenburger and Mr. Barrière added the sodium hyposulphite to the concentrated solution, and then heated the resulted mixture, I believe the precipitation was due to the above action of heat rather than to a precipitation by the sodium hyposulphite. In a 10 per cent. solution of the yttrite group, oxides, I obtained but a slight precipitation with sodium hyposulphite, which, on re-solution and treatment, did not again precipitate.

Barrière's methods introduce titanium and zirconium, both of which are exceedingly difficult to separate afterwards.

To obtain the pink color of the erbium oxide it must be exceedingly pure. One can easily be misled by the color of these rare oxides when in combination. Some when alone are white, yet when combined are of a dark color, even brown.

In order to obtain a larger sample of "lucium" to work with, I took 1 kilo of an average of several hundred samples of North Carolina monazite sand, carefully following Mr. Barrière's method, making, however, each separation thoroughly, and failed to obtain any earth answering to the reactions of "lucium," only getting as a result less than 1 per cent. of the mixed oxides of the yttrite group of a buff color and very freely soluble in dilute acids.

Since making these experiments, much work has been done by Dr. William Crookes and others to prove that "lucium" is not entitled to a place in the list of elements, but is impure yttrium.

NOTES AND COMMENTS.*

ASPHALTUM IN THE ISLAND OF BARBADOES.

In the Island of Barbadoes, West Indies, says the London *Engineer*, the discovery was made some months back of large quantities of a certain mineral —locally called "manjak"—which bids fair to outrival in point of utility all the similar substances that occur in various parts of the world. Manjak is of a black color, possessing high luster, and having a bright conchoidal fracture, in appearance closely resembling newly-broken pitch. In Barbadoes it is found very near, and sometimes upon, the surface of the ground in seams varying from 1 foot to 2 feet in thickness, running usually at an angle of about 40° and in close proximity to rocks. It is supposed to have been formed by the drying up and consolidation of petroleum, which occurs in abundance in the same localities, and is often seen oozing out of the ground or floating down the streams. In composition it is not unlike Trinidad pitch, the Utah gilsonite and the Canadian albertite, but is of superior quality to any of these. It is supposed to equal the Egyptian asphaltum in quality, but there is a doubt as to the correctness of this view. The analysis of the best quality manjak is: Moisture, 2·00; volatile organic matter, 70·85; non-volatile organic matter, 26·97; mineral matter, 0·18; total, 100·00. As ordinarily met with, however, it does not quite come up to this analysis. It contains rather more—about 5

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[*] From the Secretary's monthly reports.

per cent.—moisture and mineral matter. Referring to the analysis of Trinidad pitch, we find that it contains between 21 per cent. and 30 per cent. moisture, and about 38 per cent. ash, so that the superior richness of manjak in natural bitumen, as compared with Trinidad pitch, is evident. Among the various uses to which manjak has been successfully applied may be mentioned: (1) As insulation for electric wires. (2) As varnishes of the best quality. (3) As bituminous concrete in asphalt roads and pavements. (4) As patent fuel, mixed with peat or other organic matter. (5) In small percentages, as an intensifier of the illuminating power of coal gas. Such satisfactory results have been obtained by its use for insulation that it is expected by some experts that it will soon supplant rubber in all waterproof work.

THE LONGEST BRIDGES.

The longest bridge in the world is that over the Tay, in Scotland, which is 3,200 meters=9,696 feet long; and the next longest is also in Great Britain, being that over the Firth of Forth, 2,394 meters = 5,552 feet in length. The following table gives, in meters and in feet, the lengths of the principal bridges in various countries:

	Meters.	*Feet.*
Tay, Great Britain	3,200	9,696
Forth, Great Britain	2,394	5,552
Moerdyck, Holland	1,470	4,820
Volga, Russia	1,438	4,715
Weichsel, Germany	1,325	4,346
Thoen, Germany	1,272	4,172
Grandenz (Elbe), Germany	1,092	3,580
Brooklyn, United States	488	1,601

The greatest single span of the Forth Bridge is 521 meters = 1,725 feet; of the Elbe Bridge, 420 meters = 1,378 feet; of the East River Bridge, 488 meters = 1,610 feet.

ACETYLENE—PRICE AND COMMERCIAL EFFICIENCY.

In an interesting article by *Julien Lefèvre* (*Revue Scientifique*, March 6, 1897; No. 10, p. 289), read before the French Association for the Advancement of Science, considerable discredit is shown toward the statements of Willson and the works at Spray, N. C., to the effect that the price has been brought to 167.44 francs ($32.18) per tonne (2,240 lbs.), counting hydraulic power at 25 francs ($4.80) per horse-power per year. In Switzerland, where there is an abundance of water-power, this power costs 100 francs ($19.20). As one horse power per hour produces 4 kilograms (8·8 lbs.) of calcium carbide, the cost here becomes about 200 francs ($38.40), and the prices quoted on market are 400 francs for over 1 tonne, or 500 to 550 francs per tonne for less than a tonne. Willson claims that he can produce the carbide for 15 to 25 francs per tonne, while Pictet says that with an improved furnace he can produce absolutely pure carbide at 85 francs per tonne, though this is not as yet realized.

Theoretically, the action of water on 1 kilogram (2·2 lbs.) of calcium carbide should produce 406 grams or 341 liters (or 1 lb. carbide should produce ·308 lbs. or 5·5 cubic feet) of acetylene according to the equation:

$$CaC_2 + H_2O = C_2H_2 + CaO.$$

A good commercial product should yield about 300 liters of gas (or one pound should yield 4·45 cubic feet), at a maximum selling price of carbide of

500 francs per tonne. If we then compare in the following table the price of other illuminants we see that the price of acetylene is not so very great when all things are considered :

COMPARISONS OF VARIOUS ILLUMNANTS.

	Price Francs.	Consumption per Carcel-hour.	Price in Francs per Carcel-hour.
SOLIDS AND LIQUIDS, PER KILOGRAM (2·2 lbs.).			
Wax candle (de l'Etoile)	2·40	80 gr'ms.	0·1920
Colza oil	1·30	45 "	0·0585
Petroleum oil	0·75	30 "	0·0225
ILLUMINATING GAS, PER CUBIC METER.			
Butterfly and Manchester Burners	0·30	137 liters.	0·0411
Benzol Burners, 30 to 40 jets		105 "	0·0315
Wenham-Star Burner		100 "	0·0300
Parisian and Industrial Burners		50 "	0·0150
Welsbach Burner		20 "	0·0060
ELECTRICITY, PER KILOWATT-HOUR.			
Arc Light, round globe, average	1·10	0·011 K. W.	0·0121
Incandescent Light		0·034 "	0·0380
ACETYLENE GAS, PER CUBIC METER.			
Violle Lamp	1.80	5·56 "	0·0100
Burners of small delivery		8·00 "	0·0144

1 gram = 0·0022 lbs.; 1 cubic foot = 28·3 liters ; 1 k. w. = 1·34 horse power ; 1 cubic meter = 35·3 cubic feet ; 1 franc = 19·2 cents. [*Progressive Age.*

TECHNICAL BREVITIES.

To lessen the danger from *acetylene* in common use, it has been proposed *to store it in solution.* Messrs. Claude & Hess propose, for this purpose, acetone, which, at the ordinary pressure and a temperature of 60° F., is capable of absorbing 300 times its volume. That is, 1 pound of acetone is capable of storing practically all the acetylene that will be generated from 1 pound of calcium carbide.——Mr. C. J. Reed, in a recent impression of the *American Electrician*, discusses the subject of *the direct production of electricity from fuel*, with incidental reference to the recently mooted processes of Jacques and Case. The author's views are pessimistic. He holds that the practical solution of the problem will depend on the discovery of new chemical elements, having properties radically different from those of any known substances.——Spring has observed that two well-polished and clean *aluminum surfaces*, brought together under pressure, and kept for eight hours at a temperature of about 625° F., *will adhere as though soldered.*——Dessing has succeeded in producing *electrode carbons*, which are claimed to fully solve all the difficulties heretofore met with in using carbon electrodes in electrometallurgical work. The new carbons are of unusual hardness, exhibit a crystalline structure, and are remarkable for purity and high conductivity. ——Zakorski refines impure *bismuth* electrolytically, using the impure metal as anode in an electrolyte of nitric acid. For cathode, pure bismuth, carbon

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1895–'96.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States in 1895–'96, is from advance sheets of [illegible]

70	Sulphur.............	L. T..	1,650	1,676	41,250	24.60	2,800	2,845	64,200	22.56
71	Est. prod. unspecified	......	....	....	5,000,000	....	....	....	5,000,000	....
	Total non-metals..	......	....	....	488,651,351	....	....	....	495,747,553	....
	METALS.									
72	Aluminum...........	Lbs..	900,000	408	495,000	*j*.25	1,300,000	590	520,000	*j*.18
73	Antimony	Sh. T.	466	422	70,332	166.42	613	556	85,700	154.32
74	Copper (*m*)...........	Lbs..	386,453,850	175,294	40,616,300	231.70	467,822,973	212,201	49,729,582	234.35
75	Gold.................	Ozs. *f*	2,265,612	*j*70,478	46,830,200	*j*664.60	2,837,965	*j*88,272	58,660,637	*j*664.60
76	Iron, pig.............	L. T..	9,446,308	9,597,449	108,632,542	10.77	8,623,127	8,761,120	91,577,610	10.45
77	Lead, value at N. Y..	Sh. T.	156,854	142,298	10,132,768	71.20	174,792	158,271	10,381,843	65.59
78	Platinum	Ozs. *f*	150	*j*.4.66	2,250	482.83	200	*j*.6.21	2,800	450.89
79	Quicksilver..........	Flks*g*	33,978	1,179	1,313,589	1114.00	33,180	1,151	1,227,660	1066.00
80	Silver, comm'l value.	Ozs. *f*	46,331,235	*j*1,441,087	30,254,296	*j*20.99	56,222,322	*j*1,748,710	37,725,178	21.57
81	Zinc	Sh. T.	81,858	74,215	5,912,890	80.04	77,637	70,432	6,074,219	86.24
	Total metals.......	......	....	....	244,290,167	....	....	....	255,985,229	....
	Grand totals.....	......	....	....	....	....	....	....	....	....

(*a*) Barrels of 300 lbs.; (*b*) 400 lbs.; (*c*) 200 lbs.; (*d*) 42 gals.; (*e*) 280 lbs. (*f*) Troy ounces. (*g*) Flasks of 76½ lbs. (*h*) Bituminous coal includes brown coal and lignite. The anthracite production is the total for Pennsylvania, Arkansas, and Colorado. (*i*) Estimated. (*j*) Kilograms or per kilogram. (*k*) Including bitumen from Texas. (*m*) The value of the copper production is calculated at 0.25c. per lb. less than the average price of Lake copper at New York.

Abbreviations: Sh. T., short tons (2000 lbs.); L. T., long tons (2240 lbs.); M. T., metric tons (2204.6 lbs.); Sq'es. squares (100 sq. ft. lapped and laid).

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1895-'96.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States in 1895-'96, is from advance sheets of THE MINERAL INDUSTRY, Vol. V, now in press. The *Journal* acknowledges its obligation to the Editor, Mr. R. P. Rothwell, for the privilege of placing the facts thus early before its readers.

MINERAL PRODUCTION OF THE UNITED STATES IN 1895-6.

Compiled for THE MINERAL INDUSTRY, Vol. V.,

By Richard P. Rothwell, editor of the *Engineering and Mining Journal.*

Number.	Products.	Customary Measures.	1895.				1896.			
			Quantity.		Value at Place of Production.		Quantity.		Value at Place of Production.	
			Customary Measures.	Metric Tons.	Totals.	Per M. Ton.	Customary Measures.	Metric Tons.	Totals.	Per M. Ton.
	NON-METALLIC.									
	Abrasives:									
1	Carborundum......	Sh. T.	113	102	$67,800	*j*$6.65	595	550	$365,612	*j*$6.65
2	Cornudum.........	Sh. T.	385	349	53,900	154.44	250	227	35,000	153.75
3	Emery............	Sh. T.	1,700	1,542	119,000	77.17	1,550	1,406	108,500	77.17
4	Garnet...........	Sh. T.	877	795	39,465	49.65	2,842	2,578	96,628	37.48
5	Grindstones........	Sh. T.	36,389	33,004	290,378	8.79	31,301	28,396	294,338	10.36
6	Millstones	......	....	....	15,925	......	....	....	14,852	......
7	Tripoli & inf. earth.	Sh. T.	1,783	1,617	26,049	16.00	2,425	2,199	31,028	14.56
8	Whetstones........	......	....	....	93,303	......	....	....	105,201	......
9	Alum..............	Sh. T.	117,900	106,959	3,537,000	33.07	77,700	70,489	2,331,000	33.07
10	Antimony ore........	Sh. T.	1,083	982	37,905	38.60	150	136	4,750	34.92
	Asbestos and talc:									
11	Asbestos...........	Sh. T.	664	602	11,837	19.66	716	650	12,670	19.49
12	Soapstone..........	Sh. T.	22,133	20,097	342,298	17.03	24,319	22,068	265.806	12.05
13	Talc, fibrous.......	Sh. T.	40,000	36,368	320,000	8.80	45.000	40,824	315.000	7.70
14	Asphalt.............	Sh. T.	25,525	23,156	170,500	7.36	20,500	19,926	66,900	3.36
15	Asphaltic limestone..	Sh. T.	5,550	5,035	16,650	3.31	3,119	2,829	8,714	3.08
16	Bitumin's sandstone.	Sh. T.	42,374	38,542	139,945	3.63	53,119	48,189	138,714	2.66
17	Barytes.............	Sh. T.	20,255	18,371	99,020	5.39	21,500	19,504	86,000	4.41
18	Bauxite.............	L. T..	18,800	19,100	56,400	2.90	17,096	17,369	68,384	3.93
19	Borax	Lbs..	13,506,356	6,126	742,850	*j*.12	15,258,014	6,921	762,900	*j*.11
20	Bromine............	Lbs..	394,854	179	102.662	*j*.57	550,285	249	143,074	*j*.57
21	Cement, nat. hydraul.	Bbls *a*	7,694,053	1,047,006	4,597,285	4.39	7,454,611	1,014,423	4,353,377	4.29
22	Cement, Portland....	Bbls *b*	749.059	135.879	1.430,089	10.52	1,032,654	187,365	1,710,151	9.12
23	Clay, refractory.....	Sh. T.	3,750,000	3,402,000	4,500,000	1.35	4,000,000	3,628,800	4,800,000	1.32
24	Clay. china.........	Sh. T.	30,910	28,035	258,431	9.22	29,418	26,688	217,551	8.15
25	Clay, common.......	Sh. T.	....	....	*i*60,100,000	......	....	....	*i*65,000,000	......
26	Coal, anthracite......	Sh. T.	51,897,297	47,081,208	80,250,652	1.71	48,855,563	44,321,768	88,105,837	1.98
27	Coal, bituminous (*h*)..	Sh. T.	137,328,600	124,584,506	123,897,958	1.00	138,463,254	125,613,864	115,827,813	.93
28	Coal, cannel.........	Sh. T.	69,747	63.274	191,804	3.03	54,660	49,587	146,488	2.95
29	Coke...............	Sh. T.	12,493,464	11,333,996	19,018,276	1.68	10,357.000	9,395,809	17,267,401	1.84
30	Cobalt oxide.........	Lbs..	6,400	*j*2,903	8,640	*j*.30	12,825	*j*5,817	16,672	*j*.28
31	Copperas	Sh. T.	14,118	12,805	69,846	5.45	11,170	10,133	52,662	5.19
32	Copper sulphate.....	Lbs..	45,000,000	20.412	1,750,000	85.73	48,732,840	21,605	1,949.313	90.22
33	Chrome ore..........	L. T..	1,553	1,578	16,795	10.64	702	713	7,775	10.90
34	Feldspar............	L. T..	22,195	22,550	104,082	4.67	22,199	22,554	112,829	5.00
35	Fluorspar...........	Sh. T.	4,000	3,628	24,000	6.61	4,000	3.628	24,000	6.61
36	Gilsonite (*k*)..........	Sh. T.	1,150	1,043	34,500	32.12	1,700	1,542	54,500	35.34
37	Graphite, crystalline.	Lbs..	377,450	172	17.286	*j*.50	405,006	184	18,225	9.90
38	Graphite, amorphous	Sh. T.	840	762	4,700	6.17	574	520	3,850	7.40
39	Gypsum.............	Sh. T.	298,572	270,864	974,219	3.59	231,649	210,152	739,799	3.52
40	Iron ore.............	L. T..	15,988,000	16,243,808	27,979,000	1.72	14.650.000	14,884,400	28,567.500	1.92
41	Lime................	Bbls *c*	*i*60,000,000	5,443,164	30,000,000	......	*i*60,000,000	5,443,164	30,000.000	......
42	Magnesite	Sh. T.	2,200	1,995	14,700	7.39	2,067	1,875	13,435	7.16
43	Manganese ore	L. T..	170,509	173,337	328,107	1.84	162,526	165,126	339.083	2.05
44	Mica, ground.......	Lbs..	740,000	335	81,956	95.40	877,000	398	37,711	94.75
45	Mica, sheet..........	Lbs..	6,200	3	6,400	*j*2.13	8,000	4	8.405	*j*2.31
46	Mineral wool.........	Sh. T.	6,989	6,340	74,962	11.36	5,953	5,400	61.714	11.43
47	Monazite............	Lbs..	1,900,000	862	114,000	132.40	17,500	8	875	109.37
48	Natural gas..........	......	....	....	12,000,000	......	....	....	10,000,000	......
49	Paints, mineral......	Sh. T.	47,084	42,705	1,086,767	25.45	54,153	49,227	973,268	19.77
50	Paints, vermilion....	Sh. T.	118	107	118,190	1105.00	96	87	94,677	1088.25
51	Paints, white lead...	Sh. T.	92,939	84,314	8,768,656	104.00	95,068	86,246	7,802.267	90.46
52	Paints, zinc oxide...	Sh. T.	22,690	20,498	1,588,300	77.43	16,799	15.240	1,259,925	82.67
53	Petroleum (crude)...	Bbls *d*	52,961,943	7,215,896	47,624,913	6.60	61,396,394	8,364,631	56,963,137	6.81
54	Phosphate rock.....	L. T..	1.098,017	1,015,587	3,296,757	3.25	863,754	877,574	2,591,262	2.93
55	Marls...............	L. T..	217,700	221,183	587,790	2.67	155,000	157,480	418.500	2.65
56	Precious stones......	......	....	....	250,000	......	....	....	200,000	......
57	Pyrites	L. T..	107,731	109,088	342,587	3.14	117,782	119.666	297,853	2.49
58	Salt, evaporated.....	Bbls *e*	12,091,265	1,535,591	5,643,383	3.61	11,156,270	1,416,846	4,828,179	3.41
59	Salt, rock...........	Bbls *e*	2,184,589	277,443	828,954	2.98	2,198,303	279,184	711,919	2.55
60	Silica, sand & quartz.	L. T..	523,640	532,018	553,128	1.04	720,399	732,925	1,076,038	1.46
61	Slate, roofing	Sq'es.	752,606	238,576	2,494,213	10.45	699,100	221,615	2,260.862	10.25
62	Slate, manufactnres.	......	....	....	392,877	......	....	....	467,575	......
63	Soda, natural........	Sh. T.	1,900	1,724	47,500	27.56	3,000	2,722	65,000	23.88
64	Soda, manufactured.	M. T..	....	167,000	3.841,000	23.00	....	158,975	3,656,425	23.00
65	Stone, limestone (flux)	L. T..	4,723,154	4,798,724	1,889,262	......	4,311,563	4,380,548	1,724,625	......
66	Stone, marble........	Cu. ft	....	....	2,888,114	......	....	....	2,600,429	......
67	Stone, onyx..........	Cu. ft	1,200	91	12,000	131.87	3,000	228	24,000	105.26
68	Stone, oölitic........	Cu. ft	4,790,422	365,108	1,005,192	2.75	4,040,999	308,111	755.891	2.45
69	Other building stones	......	....	....	26,269,943	......	....	....	27,219.484	......
70	Sulphur.............	L. T..	1,650	1,676	41,250	24.60	2,800	2,845	64,200	22.56
71	Est. prod. unspecified	......	....	....	5,000,000	......	....	....	5,000,000	......
	Total non-metals..	......	....	....	488,651,351	......	....	....	495,747,553	......
	METALS.									
72	Aluminum...........	Lbs..	900,000	408	495,000	*j*.25	1,300,000	590	520,000	*j*.18
73	Antimony	Sh. T.	466	422	70,332	166.42	613	556	85,700	154.32
74	Copper (*m*)...........	Lbs..	386,453,850	175,294	40,616,300	231.70	467,822,973	212,201	49,729,582	234.35
75	Gold................	Ozs. *f*	2,265,612	*j*70,478	46,830,200	*j*664.60	2,837,965	*j*88,272	58,660,637	*j*664.60
76	Iron, pig............	L. T..	9,446,308	9,597,449	108,632,542	10.77	8,623,127	8,761,120	91,577,610	10.45
77	Lead, value at N. Y..	Sh. T.	156,854	142,298	10,132,768	71.20	174,792	158,271	10,381,843	65.59
78	Platinum	Ozs. *f*	150	*j*.4.66	2,250	482.83	200	*j*.6.21	2,800	450.89
79	Quicksilver..........	Flks *g*	33,978	1,179	1,313,589	1114.00	33,180	1,151	1,227,660	1066.00
80	Silver, comm'l value.	Ozs. *f*	46,331,235	*j*1,441,087	30,254,296	*j*20.99	56,222,322	*j*1,748,710	37,725,178	21.57
81	Zinc	Sh. T.	81,858	74,215	5,942,800	80.04	77,637	70,432	6,074,219	86.24
	Total metals.......	......	....	....	244,290,167	......	....	....	255,985,220	......
	Grand totals.....	......	....	....	....	......	....	....	....	......

(*a*) Barrels of 300 lbs.; (*b*) 400 lbs.; (*c*) 200 lbs.; (*d*) 42 gals.; (*e*) 280 lbs. (*f*) Troy ounces. (*g*) Flasks of 76½ lbs. (*h*) Bituminous coal includes brown coal and lignite. The anthracite production is the total for Pennsylvania, Arkansas, and Colorado. (*i*) Estimated. (*j*) Kilograms or per kilogram. (*k*) Including bitumen from Texas. (*m*) The value of the copper production is calculated at 0.25c. per lb. less than the average price of Lake copper at New York.

Abbreviations: Sh. T., short tons (2000 lbs.); L. T., long tons (2240 lbs.); M. T., metric tons (2204.6 lbs.); Sq'es. squares (100 sq. ft. lapped and laid).

or platinum is used. The pure metal is separated on the cathode, from which it may readily be removed and collected. It is then washed with dilute nitric acid, rinsed and fused.—The authorities of the General Italian Exhibition, to be held in Turin, 1898, announce a "*Galileo Ferraris Prize*," of 15.000 francs, to be granted for the most important application of electricity to industrial uses. The prize is open to international competition.

ELECTRIC RAILWAYS IN EUROPE.

Mr. Thomas Ewing Moore, commercial agent for the United States at Weimar, Germany, has submitted to the State Department, Washington, an interesting report concerning electric railways in Europe. He states that electric locomotion is gradually gaining ground in the various European countries, though not to the same extent as has been the case in the United States During the year 1895 the total number of electric railways or tramways in Europe rose from 70 to 111 ; the length of lines from 435 to 560 miles, and the output of the "centrals" from 18,150 to 25,095 kilowatts, while the number of cars increased from 1,236 to 1,747.

The mileage of electric railways in the principal European countries is as follows: Germany, 252 miles; France, 82 miles; Great Britain and Ireland, 66½ miles; Austria-Hungary, 44 miles; Switzerland, 29 miles, and Italy, 24¾ miles. Servia, Russia, Belgium and Spain have but from 6¼ miles to 18½ miles, while the remaining countries have less than 5 miles each.

Of these 111 lines 91 are operated on the overhead surface system, 12 on the underground system, and 8 by means of accumulators. It is estimated that the new lines projected for the present year will exceed in number and mileage those constructed during any previous year. Considerable activity exists in planning and laying out new routes.

The capital invested in electric lines in Germany alone is estimated at $23,800,000. German electrical companies and supply manufacturers have greatly increased in number and capital during the past few years. Berlin is about to introduce general electric locomotion in its streets, and the electric street railways in Hamburg and Leipsic are about completed.

The overhead system, Mr. Moore states, will be preferred for the lines contemplated, or in course of construction, on account of its cheapness.

BOOK NOTICES.

Encyclopédie des Aide-Mémoire. Librarie Gauthier.—Villars et Fils. Paris (Small 8vo. Price per volume, 2.50 francs, unbound; 3 francs, bound.)

Since our last notice of this condensed series of technical subjects, the following additional volumes have appeared, As previously noticed, each of these volumes treats of a special subject, and is substantially complete in itself:

Henriet (*H.*), ancien Élève de l'École de Physique et de Chimie industrielle de la Ville de Paris, Chimiste à l'Observatoire de Montsouris. Les gaz de l'atmosphère.

Vallier (*E.*), Chef d'escadron d'Artillerie, Correspondant de l'Institut. Projectiles de campagne de siège et de place. Fusées.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage aux gaz, aux huiles, aux acides gras.

Loppé.—Accumulateurs électriques.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage électrique.

Urbain (*V.*), Ingénieur des Arts et Manufactures, Répétiteur à l'École Centrale. Les succédanés du chiffon en papeterie.

Fabry (*Ch.*), ancien Élève de l'École Polytechnique, Maître de conférences à la Faculté des Sciences de Marseille. Les piles électriques. W.

Hydraulic Cement: its properties, testing and use. By Frederick P. Spalding. New York: John Wiley & Sons. London: Chapman & Hall, Limited. 1897. 12mo, cloth, $2.

This volume should prove of much practical value to engineers engaged in construction work, requiring the use of hydraulic cements. It presents, in condensed and readily comprehensible form, the most recent views respecting the nature and properties of these materials, and a discussion of the merits of the various methods of testing cements that are in vogue. An appendix contains a number of sample specifications used by prominent railway companies, municipal bureaus, etc. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 16, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 16, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 37 members and visitors.

Additions to membership since last report, 12.

In reference to the preamble and resolutions bearing on the abatement of the smoke nuisance, referred by the Institute at its last stated meeting to the Board of Managers, with the request that the Board would report on the expediency of their adoption, the Actuary reported that the Board had adopted the following resolutions at its stated meeting of June 9th, viz.:

Resolved, That in view of the importance of the subject and the necessity of having any deliverance by the Franklin Institute carefully considered, the Board of Managers recommend that formal action be deferred until every member of the Institute shall have had the opportunity of reading the discussion as it will appear in the *Journal*.

Resolved, That the Board will present resolutions covering the subject, with its recommendations, to an early meeting of the Institute.

Mr. Howard Murphy, civil engineer, read a paper entitled: "A General System for the Sewerage of Suburban Philadelphia." Referred to the Committee on Publications, with the view of placing in type for distribution to members for discussion at the stated meeting of September 15th.

Prof. George A. Hoadley, Swarthmore College, presented an informal communication on "Observations Relating to Thunder Storms," illustrated with several lantern slides. Referred for publication.

A communication from Col. C. Walseley Cox, on the "Hutchinson Smoke-Consuming Furnace," was deferred on account of the illness of Col. Cox.

The Secretary's report embraced a reference to the industry of mining monazite for the production of the rare earths used in the manufacture of the mantles for the Welsbach incandescent light. Also, an explanation of, and experimental demonstration with, the Burton Electric Liquid Forge.

Action on the election of a successor to the late John H. Cooper, on the Committee on Science and the Arts, and on this Committee's report of the record in the case of the Shaw gunpowder tester, was postponed until the stated meeting of September 15.

Prof. Joseph W. Richards was appointed as the delegate of the Institute to the Seventh International Geological Congress, about to meet in St. Petersburg, Russia, and the Secretary was directed to provide Professor Richards with the needful credentials.

The Secretary was further directed to ascertain whether the name of the Institute was being used in an unauthorized manner for the purpose of obtaining an appropriation of money from the Legislature of the State of Pennsylvania, and in such case to make such explanations and corrections by correspondence as the facts would appear to warrant.

Adjourned.

Wm. H. Wahl, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held June 1, 1897.*]

Mr. James Christie in the chair.

Reports on the following subjects passed first reading:

The Phantascope, C. Francis Jenkins, Washington, D. C.

All-Wrought Steel Pulley, Thomas Corscaden, Philadelphia, Pa.

Rochester Time Recorder. Willard & Frick Manufacturing Company, Rochester, N. Y.

Reports on the following subjects were adopted:

Typewriting Machine.—John L. Williams, New York.

Abstract.—This is a keyboard type-bar machine, having the type-bars divided into two groups, before and behind the platen, at the top of the machine, the types striking the platen and printing on top. The movement of the type-bar is similar to that of the upper limb of a parallel ruler, set on edge and carrying a type on the end of the upper limb, resting on an inked pad when in position, as if the two limbs were together, and striking the platen when extended.

Each type-bar (of which there are twenty-eight) carries three letters or characters, as may be, and the platen has two shafts, bringing all of them (eighty-four) into action. The paper passes down on both sides of the platen, and is rolled in cradles provided for it on both sides.

The printing is in full view of the operator, and is done directly from the type, which gives to the printing a sharpness not attainable with the usual method of printing through a ribbon. Protected by U. S. Letters-Patent, No. 523,028, July 17, 1894; No. 501,753, July 18, 1893; No. 442,697, December 16, 1890.

The report considers some eighteen claims of merit adduced by the applicant, and finds that the greater number of these are more or less completely substantiated. The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—G. M. Eldridge, Hugo Bilgram, J. Logan Fitts, Wm. C. Head.]

Method for the Trisection of the Angle.—Charles Morrell, Chicago, Ill.

ABSTRACT.—Applicant submits a general method for the trisection of an angle. The sub committee charged with the investigation applied the method described by applicant to angles selected at random, and found it to be incorrect by analytic and graphic methods. [*Sub-Committee.*—L. F. Rondinella, Edwin S. Crawley, Edgar Marburg, Hugo Bilgram.]

Gear-Moulding Machine.—Samuel Groves, Pittsburgh, Pa.

ABSTRACT.—This machine belongs to the type of gear-moulding machine introduced some twenty-five years ago by Craven Bros., of Manchester, England, and subsequently modified by various inventors, notably by Walker (1881), and Kepp (1890). They consist, generally speaking, of a revolving table for carrying the flask, and a swinging arm supported on a column or bracket at one side of the table for carrying the pattern sections and sweeps. The table is provided with devices for centering and leveling the flask, and for rotating it intermittently, to space the teeth of the wheel to be moulded. The swinging arm is provided with an adjustable pattern holder at its outer end, and can be swung out of the way when the flask is to be removed. It is in the mechanical details of a machine of this class that the applicant claims to have made improvements. For these the reader is referred to applicant's U. S. Letters-Patent, No. 573,783, December 22, 1896.

The report finds that Mr. Groves' improvements involve few elements of novelty, and that they are of minor importance, some of them being of the nature of refinements in mechanical details that will be of doubtful utility in a machine to be exposed to the dust, dirt and rough usage prevailing in the foundry. [*Sub-Committee.*—Thos. P. Conard, J. Sellers Bancroft.]

Flying Machine.—Praull Aëromotor Company, Philadelphia.

ABSTRACT.—The basis of this machine is a differential piston engine by which the power is applied directly to screw-vanes, and by which a differential movement of the vanes is produced, (*i. e*, a quick revolving down-stroke and a slow up-stroke), to secure the same effect as that of the wing of a bird when flying. The vanes are set opposite each other at the forward and rear ends of the car to be propelled. Applicant submits a crude and inoperative model, with which the committee is unable to make a demonstration. In view of this fact the report finds that the inventor has failed to sustain his claims. [*Sub-Committee.*—Wm. M. Barr, John H. Cooper, Tinius Olsen.]

Automatic Safety Device for Electric Circuits.—Lewis G. Rowand, Camden, N. J.

ABSTRACT.—This invention is intended to be an improvement in automatic safety devices for electric circuits, and is claimed to be particularly adapted to cut off the current from a section of a trolley line, which, from any cause, may become broken, or from which it is desirable to cut off the current, as in the case of a fire. The system will be found fully described and illustrated in the *Journal* (*vide* J. F. I., Vol. CXLIII, p. 357, *et seq.*, May, 1897). The system is protected by U. S. Letters-Patent, No. 570,852.

The finding of the report is to the effect that the apparatus accomplishes all that is claimed for it, and that the combination of devices for the purposes named has not been anticipated. It is believed, however, that the cost of properly equipping a trolley road with the Rowand devices would be prohibitive. For the general merit of the device, the Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—E. A. Scott, C. H. Bedell, C. W. Pike.]

Automatic Fluid-Pressure Friction-Clutch.—George M. Richards, Erie, Pa.

ABSTRACT.—The purpose of this invention is to facilitate the transmission of motion from one shaft to another, performing in this operation the same function as is performed by the numerous friction-clutches at present in use. The Richards device is an improvement upon the fluid friction-clutches of Brayton (1880) and Jones (1890).

Following is a brief general description: On the shaft to be driven is secured a flange, which is enclosed by a shell or housing, to which latter is secured the driving pulley. The frictional contact necessary to communicate motion from the housing and driver to the friction flange and shaft is obtained by means of fluid pressure forcing the housing and friction flange together, the friction being automatically produced by a pump, which is operated through the relative difference of motion of the two main parts of the clutch, viz.: the friction flange and the housing. For specific details the reader is referred to applicant's U. S. Letters-Patent, No. 574,823, January 5, 1897.

The report finds that the invention displays much ingenuity, and especially commends as meritorious that feature of its operation by which the friction is automatically increased as may be needed. This favorable opinion is qualified, however, by the statement that it is complicated and costly, liable to become disarranged, and, when out of order, difficult to repair. It is admitted, however, notwithstanding these objections, that there may be situations where the Richards Clutch could be used with advantage.

For the ingenuity displayed in making the friction-clutch automatic in action, which appears to be original with this invention, the Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—Tinius Olsen, Wm. M. Barr, Thos. P. Conard.]

Metallic Corner Bead.—Edward B. Marsh, Lexington, Mass.

ABSTRACT.—This is a device for protecting the corners of wall plastering, and is substantially a metallic substitute for the common rounded wooden corner-bead in general use. It is formed of rolled metal with a rounded edge and provided lengthwise on either side with one or more recesses into which the plaster may flow and permit effectual contact. The bead piece is supported by clips of flat metal, formed by slitting one end, thus making two ends. These are bent so as to embrace the corner bead by entering the recesses in its side. The other end of the metal strip is provided with holes by which it is secured to the studding with nails.

The report finds the invention to be a practical and inexpensive means of accomplishing its intended purpose of providing a substantial and neat metal corner bead, which will render the plaster less liable to be chipped or broken at the point of union. Protected by U. S. Letters-Patent No. 562,783, June 23, 1896. The invention is commended for simplicity, practicability and durability. The Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—H. R. Heyl, Chas. A. Hexamer.]

Investigations on the Molecular Physics of Cast Iron.—Alex. E. Outerbridge, Jr., Philadelphia.

ABSTRACT.—These investigations have their origin in the observation made by the author that certain test bars of cast iron exhibited unexpected deviations from the strength which they were expected to exhibit. The only assignable cause for the abnornal (increased) strength of these pieces, which came to light in the examination of the facts of the case, was the fact that these specimens—contrary to the usual custom—had, previous to testing, been cleaned in a tumbling barrel.

The outcome of these observations was a carefully conducted series of experiments to determine the influence of vibration on cast iron. Experiments with a number of test bars cast from one pattern and one runner, some cleaned in the tumbling barrel and others with a wire brush, showed that those which had been subjected to concussion in the mill, were from 10 to 15 per cent. stronger than the others.

It occurred to the author that this increase in strength might be due to the "mobility of cast iron at ordinary temperatures when subjected to repeated shocks." To test the correctness of this hypothesis, a number of newly cast test bars were subjected to 3,000 taps from a hammer upon one end. When these were compared for strength with other untreated bars from the same set, they showed the same proportionate increase of strength as had been observed with the bars cleaned in the tumbler. Numerous other experiments confirmed the fact that a substantial increase of strength, amounting in some cases to as much as 35 or 40 per cent., was exhibited by specimens of cast iron when subjected to preliminary repeated shocks.

Mr. Outerbridge has formulated the results of his scientific study of these phenomena in the statement that the molecules of cast iron are capable of movement without the necessity of heating the mass (as in ordinary annealing) and that by the methods above described, a species of "molecular annealing may be effected in cast iron at the ordinary temperature, which will release the strains in the castings, precisely as does annealing by slow cooling in heated ovens or pits." (For a detailed account of the author's experiments and conclusions, the reader may refer to the *Transactions* of the American Institute of Mining Engineers, for the year 1896, and this *Journal*, Vol. CXLII, p. 148, August, 1896.)

The report finds that while it has long been known that a certain molecular change takes place in cast iron in the course of time, and that this change tends to relieve the internal strains and render the casting tougher, Mr. Outerbridge has been the first to make a careful study of the phenomena, and to note that this change may be hastened by impact, and the whole effect produced in a short time.

The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee*—C. J. Prince, Wm. C. Henderson.]

Screens for Photo-Mechanical Engraving.—Louis E. and Max Levy, Philadelphia.

This invention relates to certain improvements in the manufacture of screens or gratings used in the production of half-tone printing blocks by photography. In the production of such half-tone engravings, the requisite grain in the negative is obtained by interposing a screen between the lens of the camera and sensitive plate. The improvements of the Messrs. Levy consist: (*a*) in a radically new system of ruling such (glass) screens or gratings; and (*b*) in a new method of mounting the screens to protect them from injury.

The earliest gratings for this purpose (by v. Egolfstein & Sartain, in 1861) were made by photography, and were lacking in sharpness of line. The Messrs. Levy corrected this defect by ruling through a ground laid upon plate glass, etching the lines thus laid bare, and, after cleaning off the remaining ground, filling the lines so etched with an opaque pigment. Two such glass plates are placed together face-to-face, so that the lines on one cross the lines of the other at right angles, the surfaces bearing the etched gratings being in the center of the system. They are thus not only in the same plane, thus insuring the maximum of sharpness, but also are completely protected from injury by the glass plates forming the outer surfaces of the combination. A pair of such glasses is cemented together with Canada balsam, and when thus finished, constitutes the completed screen.

The second improvement of the Messrs. Levy relates to the character of the lines of the grating and to the graduated photographic effects obtainable from the intersections of the two ruled plates. (For the details of this mode of ruling the reader is referred to the report and to the patent specification.)

The report commends these improvements highly, and refers to the fact that the "value of the improvements of the Messrs. Levy has been widely recognized by the workers in half-tone, and have given a world-wide renown to the Levy screens; so that now nearly every photo-engraving establishment in both America and Europe employs them."

The improvements above referred to are covered by U. S. Letters-Patent No. 492,333, February 21, 1893, and No. 521,659, June 19, 1894.

The award of the John Scott Legacy Premium and Medal is recommended to the inventors. [*Sub-Committee.*—D. Anson Partridge, Samuel Sartain, Hugo Bilgram, Coleman Sellers, John Sartain.]

CHEMICAL SECTION.—Stated meeting, Tuesday, June 15, 8 P.M.

The meeting was devoted to a lecture by Prof. Joseph W. Richards, Lehigh University, Bethlehem, Pa., President of the Section. *Subject.*—"A Critical Review of Methods of Determining Minerals." (Referred for publication in full.)

ELECTRICAL SECTION.—No meeting.

SECTIONS.

Mining and Metallurgical Section.—Stated meeting Wednesday, June 9th; Mr. Benjamin Smith Lyman, President, in the chair.

Mr. H. B. C. Nitze, Chemist to the Wetherill Concentrating Company, Bethlehem, Pa., presented a paper "On Monazite," giving its chemical and mineralogical characteristics, occurrence (chiefly in North Carolina and Brazil) and industrial application for manufacturing the rare earths used in the production of the mantles for the Welsbach light. The interesting fact was noted that the annual production of this once so-called rare mineral now exceeds 1,000,000 pounds. The finding of the mineral naturally concentrated in sea-beach deposits on certain portions of the Brazilian coast, whence it is shipped as ballast, has so greatly reduced the price, that the mining of the mineral in North Carolina has been abandoned as unprofitable. The paper was illustrated by an exhibit of the salts of the rare earths produced from monazite, shown by Mr. Waldron Shapleigh, chemist to the Welsbach Light Company.

Mr. Charles James, superintendent of the steel department of Henry Disston & Sons, described "A Special Process for Treating Cast Iron." White iron, with approximately 2·40 per cent. combined carbon and 0·4 per cent graphitic carbon, is used for the purpose. The castings are placed in a muffle furnace, in which they are subjected to the action of a secret composition (said to be a powerful, volatile oxidizing agent) and maintained at a temperature slightly below fusion for five or six hours. The product may be forged and tempered and shows a remarkable increase in tensile strength. The total carbon in the product seems to be the same as in the untreated iron, but combined carbon has been substantially altered into a finely disseminated uncombined carbon. Doubts were expressed in the discussion which followed, whether the result was not due entirely to the annealing, rather than to the "medicine." The prolonged annealing was thought to be a sufficient explanation of the facts. The process is in commercial operation in a large foundry in Philadelphia, producing hatchets, hammers, etc.

Dr. D. K. Tuttle, melter and refiner at the U. S. Mint, in Philadelphia, gave an informal account of an examination he had been officially called on to make in connection with an alleged discovery of a process of transmuting base metal into gold. The investigation proved the fallacy of the alleged discovery, but disclosed the interesting circumstance that practically all the product sold as "pure" antimony by the best-known chemical houses, contains distinct traces of gold.

The Section adjourned over the summer recess, to reconvene on September 8th, when Capt. Zalinski will lecture on "Japanese Swords," illustrating the subject with the aid of his large and valuable collection of these remarkable products of the metallurgical art.

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THE UTILIZATION OF ALUMINUM IN THE ARTS.*

BY ALFRED E. HUNT.

President of the Pittsburgh Reduction Company.

Until the present decade, the attention and research of everyone interested in the metal aluminum were directed almost exclusively to problems connected with the cheap production of the metal by means more adapted for large commercial operations than by the processes by which it had previously been manufactured.

The prevailing and popular opinion had been that if anyone should be fortunate and skilful enough to produce aluminum so cheaply that it could be sold at a profit at the price of a dollar per pound, the consumption of the metal would become enormous; and if it could only be sold at the price of 50 cents per pound—a price which, taking its relative specific gravity into account, would nearly approach that of copper and brass —the demand for the metal would be prodigious, and the profits which would accrue to the manufacturers would be of such fabulous amounts as simply to take one's breath away to attempt to estimate them.

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*A lecture delivered before the Franklin Institute, March 26, 1897.

Much of this sort of speculation has it been my lot to hear, and, I may truthfully say, to endure, from inventors of processes for the manufacture of aluminum (in my investigation as to their relative values), which have since proved to be either chemically impossible or commercially impracticable.

Early in the progress of the Pittsburgh Reduction Company in the manufacture of aluminum, working with the Hall process, I had my attention sternly called by the necessities of the case to the fact, which further and larger experience has simply verified, that the problems connected with the promotion of the sale of aluminum, its adaptability for various purposes, and the utilization of the metal and its alloys in the arts, were as difficult of solution as the problem of cheapening the processes for its production, and required as much research; offering a great many more opportunities for remuneration than would the search for cheaper modes of production.

The exploiting on a considerable commercial scale and the perfecting of the details of the Hall process, as carried on by the Pittsburgh Reduction Company at its several works at Niagara Falls, N. Y., and New Kensington, Westmoreland County, Pa., have already permitted the selling price for aluminum in large quantities to be placed much below the relative price for copper and somewhat below the relative price for brass.

Aluminum is now selling in large quantities at 31 and 32 cents per pound, in ingots; and the relative increase in price for sheets, plates and bars, over the price for ingots, is not greater than that charged for either of the metals copper or brass.

Copper sheet, according to the Official Copper Manufacturers' price-lists, has a specific gravity of 8·93, and brass sheet varies (as it does also in composition) from 8·15 to 8·20 specific gravity. Aluminum sheet runs from 2·62 to 2·66 specific gravity. On the basis of their specific gravities, copper can be reckoned as being 3·3 times heavier and brass 3·15 times heavier than similar sections of aluminum.

The consumption of the common metals in the United States during 1895 was as follows:

	Short Tons.
Copper	156,000
Brass	60,000
Zinc	89,686
Lead	161,440
Tin	27,126
Nickel	375

The output of aluminum in the United States during 1896, which was practically all consumed within that period, was only about 1,300,000 pounds; and the output for the year 1897 will be about 2,000 tons, and of this, I estimate a consumption of only about 1,000 net tons in the United States.

While the partial replacement of brass by aluminum will undoubtedly take place, in accordance with the law of the "survival of the fittest," nevertheless, so great is the conservatism of tradespeople, that it will be only slowly that its relative merits and relative cheapness will win for aluminum its eventual position in importance as compared with the other common metals of large tonnage consumption, such as copper, brass, zinc, tin and lead. It has already met and outdistanced nickel in the amount of its consumption.

While the output of less than 2,000 tons of aluminum, in the year 1897, is very small as compared with the consumption of 156,000 tons of copper and 60,000 tons of brass during the year 1895, in the United States, and while it is a fact that aluminum is now offered at prices considerably lower than copper for any given purpose, and fully as low as brass in many cases, nevertheless, the Pittsburgh Reduction Company will be quite satisfied if its entire output for the present year is taken by the trade.

In a general way, the uses of aluminum have enlarged very much during the past eight years; and, from a consumption, in 1889, of not over 100 pounds of aluminum per annum in the United States (selling at not less than $8 per pound), the metal has pushed its way to the front to a consumption of over 600 tons in the year 1896. This lecture is given to outline in a general way the uses that have thus far been suggested for aluminum, and to give some account of properties of the metal and its alloys which have caused its demand in the arts.

As one of the most important uses of *aluminum* has been its utilization *in the manufacture of steel ingots and steel castings*, I think it well to commence with this special use of the metal.

Many attempts have been made to alloy aluminum in various proportions with iron and steel; but thus far no very satisfactory results regarding its use in iron have been obtained.

The influence of aluminum seems to be as a softener, rather than a hardener, for iron; and the more common use of alloying metals, as hardeners with steel, is therefore precluded in this case.

Aluminum combines with iron in all proportions, but an alloy of 50 per cent. aluminum and 50 per cent. iron, while casting into a solid mass, in a short time will crumble into a powder.

Aluminum is largely used in the manufacture of steel, the amount of aluminum used, however, being comparatively very small and varying with the grade of steel being made, the amount of occluded gases, the temperature of the molten metal, the size of the ingots or castings, etc.

In the manufacture of open-hearth steel ingots, the proportion of aluminum used is from 2 to 4, or at most 5 ounces of aluminum to the ton of steel; the aluminum being added in the ladle, as in the case of steel castings, or (with more economy in the use of the aluminum, and in accordance with the general practice in the United States) as the steel is being poured into the ingot moulds or groups of moulds. Until the proper proportion of aluminum to add in any particular grade of steel has been determined experimentally, it is advisable to start with small lots, for instance, with 2 ounces to the ton of steel, increasing to, say, 5 ounces of aluminum per ton, according to the amount which is found necessary, noting the character of the results obtained.

It has been found that Bessemer steel ordinarily requires from 1 to 3 ounces more aluminum per ton of steel than similar grades of open-hearth steel, in order to have the same effect.

A steel which has become "wild," as it is called by the melters, or oxidized and overheated, requires considerably increased amounts of aluminum over what is used to advantage in ordinary cases.

The special advantages to be gained by the use of aluminum in steel manufacture are as follows:

(1) It increases the soundness of tops of ingots and consequent decrease of scrap and other items of loss, which more than compensates for the cost of the small amount of aluminum added.

(2) It quiets the ebullition in molten steel, thereby allowing the successful pouring of "wild" heats from furnaces, ladles, etc.

(3) It improves the homogeneity of the steel:

(*a*) By preventing oxidation.

(*b*) By that property of aluminum in virtue of which it rapidly permeates the body of the steel, thereby increasing the ease with which other metals will alloy homogeneously with steel.

(*c*) By decreasing the time that steel will remain fluid after being poured into moulds and causing the steel when solidifying to do so more evenly, preventing a central core remaining molten longer than the outside portion of the metal, and in this way stopping the segregation of phosphorus and other impurities in the "mother liquor" of the metal remaining molten the longest.

(4) It increases the tensile strength of steel without decrease of the ductility.

(5) It removes any oxygen or oxides that may be in the steel, the aluminum acting, in the same way as manganese does, as a deoxidizer. Good steel has been made for electrical purposes, using aluminum entirely in the place of manganese, to remove occluded oxygen and oxides from the molten steel and render it malleable.

(6) It renders the steel less liable to oxidation in casting. This is occasioned by preventing the continued exposure of

fresh surfaces of the molten steel in its ebullition in the moulds after pouring.

(7) It permits the production of smoother surfaced castings and ingots of steel than it is possible to obtain without the use of aluminum.

The chief advantage in the use of aluminum in steel is that first named, *i.e.*, increasing the soundness of the tops of steel ingots and decreasing the scrap and other loss; and for this purpose the use of aluminum in the manufacture of steel is now becoming almost universal with the principal steel manufacturers, not only in this country, but also in Europe.

The phenomenon of quieting steel by the use of the very small proportion of aluminum referred to, is a very important and remarkable one.

Steel poured from a ladle into an ingot mould without being treated would ordinarily boil for ten to fifteen minutes before "freezing over" at the top, and when freezing would rise in the moulds for 8 or 10 inches, with ordinary steel of ten-hundredths to twenty-hundredths of one per cent. carbon, unless heavy chills are placed on the tops of the ingots. When aluminum is added, however, the steel will come up to the required level and remain there, freezing over within thirty to forty-five seconds after the last of the steel is poured into the ingot mould.

Comparative results of the use of aluminum in steel can readily be shown by pouring two ingots side by side, from the same ladle of molten steel, one treated with aluminum in the ingot mould and the other not so treated.

There is danger in adding too large a quantity of aluminum to ingot steel, in which case the metal will settle very solidly and will be liable to form deep "pipes" in the ingots. To add just the right proportion of aluminum to the steel requires some experience on the part of the steel manufacturer.

This danger of the piping of the metal is not a serious one in ingot steel if care be taken to determine just the right proportion of aluminum to use, in order to prevent the formation of too many blow-holes at the top of the ingot. With the metal entirely solid—that is, with too much aluminum added

—the shrinkage, due to contraction, will produce pipes, which will occasion a serious amount of crop ends or defective steel at the top of the ingots.

In the case of the manufacture of steel castings, this trouble is not experienced; the problem is simply to get a solid steel casting, and much larger proportions of aluminum are added in castings than in the practice of making steel ingots, the piping, due to shrinkage in the metal, being taken care of in the large "riser" or sinking-head, which is provided for steel castings.

No difficulty has been experienced with the thorough mixing of the aluminum added to steel, as it seems rapidly and uniformly to permeate the metal without any special care being taken in stirring. This property aids in the homogeneous alloying of nickel and other similar metals to steel as well; and steel manufacturers use aluminum in addition to nickel for this purpose.

Mr. R. A. Hadfield, of Sheffield, England, says that the influence of aluminum in steel appears to be like that of silicon, though acting more powerfully. The same writer (who is confirmed by Howe and Osmund) claims that an addition of aluminum does not lower the melting point of steel, *i. e.*, that the critical point is about the same whether aluminum be present or not. It is the aim, however, in adding aluminum to iron or steel, to add just enough to combine with all the oxygen present, but to leave no trace in the ingot or casting; any more than this is not required.

Mr. J. E. Stead states that in a case where aluminum had been added to ordinary soft open-hearth steel with properly prepared moulds, the castings were very sound indeed. The test bars, which were cast about 8 inches long by ¾ inch square, were perfectly sound, and had a tensile strength of 40,000 pounds per square inch; whereas the same bar, without aluminum, only stood 20,000 pounds, the reason being that in the ordinary steel without aluminum the cavities were very numerous. A few hundredths of one per cent. of aluminum in that casting increased the weight and solidity and reduced the blow-holes by 23 per cent.

There are no such metals as "aluminum steels" in the same sense that there are "nickel steels" and "chromium steels" Aluminum is not a hardener of steel, and none of its alloys with steel in material proportions has so far proved advantageous. It has been proved that the addition of aluminum to steel just before "teeming" causes the metal to lie quiet and give off no appreciable quantity of gases, producing, as previously stated, ingots with much sounder tops.

There are two theories to account for this: one, that the aluminum decomposes these gases and absorbs the oxygen contained in them; the other, that aluminum greatly increases the solubility in the steel of the gases which usually are given off at the moment of setting, thus forming blow-holes and bubbles.

Probably both of these causes operate to produce the desired effect, but the well-known affinity of aluminum for oxygen would point to the former as being the chief action, *i. e.*, in combining with both the carbonic oxide and the dissolved oxide of iron which may be present. Professor Arnold has shown that blow-holes in steel and iron are caused partly by the presence of carbonic oxide gas in the metal, and this gas is decomposed by the aluminum which unites with the oxygen, forming alumina, or oxide of aluminum, setting free the carbon, which appears as uncombined carbon or graphite. It also combines, in some way not yet determined, with the hydrogen and nitrogen present, absorbing the gases or rendering them more soluble in the steel. Aluminum also sets free much of the carbon remaining in the steel, as the following result, obtained by Mr. R. A. Hadfield, will clearly show. Believing that aluminum, like silicon, will cause a precipitation of graphite, he added between 3 and 4 per cent. to ordinary spiegel (with 12 and 25 per cent. manganese). The result was, in both cases, a complete change from the well-known spiegel fracture to that of ordinary close No. 3 gray pig iron.

	C. C.	Gr. C.	Si.	Mn.	Al.	
Spiegel.						
12 per cent. before addition of Al. .	4·80	none.	—	13·65	—	Non-magnetic susceptibility unaltered. Fracture changed from usual pronounced "spiegel" appearance to that of No. 3 iron.
12 per cent after addition of Al. .	·93	3·45	1·30	11·75	3·19	
25 per cent. before addition of Al. .	4·10	—	—	25·20	—	Do. except the change was not quite so decided. There was considerable loss of aluminum.
25 per cent. after addition of Al. .	2·30	1·88	2·16	22·16	1·24	

Aluminum is the principal deoxidizer known to metallurgists, the next in efficiency being silicon. Their relative values are as follows: 100 parts by weight of oxygen will combine with 114 parts of aluminum, or with 140 parts of silicon, or with 350 parts of manganese. This, however, does not correctly express the value of aluminum as a deoxidizer of iron and steel, as it has so great an affinity for oxygen that it will entirely disappear if there is any oxygen present, and will be found in the steel and iron only after all the oxygen contained therein has been absorbed. This is not the case with either silicon or manganese, as either or both of these are often found in the steel when oxygen is present. There is also an additional inducement for the steel maker to use aluminum, namely, in the cost, for the use of silicon will add from 87 cents to $1.12 to the cost per ton of steel, while sufficient aluminum will not add over 10 cents, and in many cases not more than 6 cents per ton, to the cost of the steel. The saving in bad castings, or unsound ingots, will repay this many times over. One large English steel maker estimates his savings from this source alone at over £2,000 per annum. The special advantage to the steel maker seems to be that aluminum combines the effects of both silicon and manganese.

In most common practice, aluminum is added to steel in the form of the pure metal. In this form, it has the advantage not only of quickly melting and homogeneously alloying, but the manufacturer knows also just how much aluminum he is adding, which is not the case if he purchases alloys of aluminum for adding to the steel.

Some manufacturers, however, prefer to use ferro-aluminum rather than pure aluminum, in their practice.

In this country, the alloy is first placed in the steel ladle, the molten steel from the open-hearth furnace or converter is run in and the alloy is melted and diffused through the steel.

Ferro-aluminum is a trade-name given to 5 or 10 or even 20 per cent. of aluminum alloyed with iron. Either a good grade of cast iron, free from sulphur and phosphorus, or of pure steel low in these elements, is the best material to be used for the purpose of alloying with the aluminum.

Most users of ferro-aluminum make their own ferro-aluminum by adding known weights of pure aluminum to known weights of steel or iron mixture with which they wish to alloy, casting the mixture into convenient moulds.

In the past, ferro-aluminum could be purchased at a cheaper rate per unit of aluminum than the pure aluminum; but this is not the case at present, as pure aluminum can be bought as cheaply as the contained aluminum in any of the alloys.

In cast iron, from 1 to 2 pounds of aluminum per ton is put into the metal as it is being poured from the cupola or melting furnace. To soft gray No. 1 foundry iron, it is doubtful whether the metal does much good; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well or give sound and strong castings, the aluminum certainly in many cases allows better work to be done and stronger and sounder castings to be made, having a closer grain, and hence much easier tooled. The tendency of the aluminum is to change combined to graphitic carbon, and it lessens the tendency of the metal to chill. Aluminum in proportions of 2 per cent. and over, materially decreases the shrinkage of cast iron.

The effect of *aluminum in wrought iron* is not very marked in the ordinary puddling process. It seems to add somewhat to the strength of the iron, but this increase is not of sufficient value to induce the general use of aluminum for this purpose. The peculiar property of aluminum in reducing the long range of temperature between that at which wrought iron first softens and that at which it becomes fluid, is taken advantage of in the well-known Mitis process for making "wrought-iron castings." It is for this that aluminum is most used in wrought iron at present.

The extreme ductility of aluminum makes it one of the readiest metals to work under the rolls. It is best to roll the larger ingots hot—that is, at a low annealing heat.

Aluminum becomes hard and loses its ductility under rolling, and therefore requires frequent annealing during the process. When the plate is soft from recent annealing, it will stand a very considerable reduction in thickness on each pass through the rolls; but as it becomes hard, the draught must be light to avoid cracking.

Aluminum can be rolled so as to be quite stiff. The hardest rolled aluminum has about the temper of hard brass.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, can be rolled into any sections into which steel is rolled.

In annealing aluminum, an even heat should be maintained in the muffle, and the metal on being withdrawn should be allowed to cool slowly. The temperature should be such that a piece of iron or steel placed in the muffle in the dark will show a red heat; for annealing the sheet, a much lower temperature will suffice. The best test as to when the aluminum has come to the proper heat is to observe whether the metal will char the end of a pine stick, which should leave a black mark behind it as it is drawn over the plate. The metal should be at this temperature throughout and not only on the surface.

Aluminum, either in the pure state or alloyed with a few per cent. of hardening ingredients, is now sold in the markets by dealers, in the form of ingots, bars, plates, sheets, rod, wire, tubing and in castings. It is fabricated into the forms described above, either by melting or casting, hot or cold-rolling, hammering or drawing, and in a limited way by the "squirting process."

Aluminum under pressure can be "squirted" through dies into almost any shape, if the temperature of from 900° to 1,000° F. be maintained in the metal.

Several devices are used for retaining the heat in the molten aluminum after it is poured into the cylinder in which it is subjected to pressure. In most of these devices the casting cylinder is on trunnions, so that the metal can be poured with the cylinder in a vertical position, after which it is changed to a horizontal position and the piston-plunger inserted and made to act on what was the bottom of the ingot as cast, while the die, giving the desired shape to the metal when drawn, is inserted at the other end. An improvement which has been patented in England, is to have the cylinder in which the metal is cast a composite one, consisting of several cylinders of metal, one within the other, the space between the various metal cylinders being filled with some good non-conducting material which has a high crushing strength; powdered granite is used as a preferable material for the purpose. By means of this device the pressure on the interior metal cylinder is conducted to the outer, thick, cool, and therefore strong cylinders, without the heat of the contained aluminum being conducted away in the same proportion as would take place without the use of the composite casting cylinder. By means of this apparatus, aluminum can be very cheaply and efficiently squirted to almost any desired section.

"Nickel-aluminum" is a trade name for aluminum alloyed with a few per cent. of hardening ingredients, the proportions varying according to the purpose for which the alloy is to be employed. The principal hardening metals so far used with aluminum are copper, nickel, zinc, manganese, tin, chromium, titanium, tungsten and vanadium. Each of these metals has a somewhat different characteristic in the alloy it produces. It has been found practicable, in the best forms of alloys so far used, to combine several of these metals to the best advantage rather than to use them singly.

A considerable difference in the character of the resulting alloy is found according as aluminum used in alloying is comparatively free or not from its two common impurities, silicon and iron. The ordinary commercial metal as now regularly sold upon the markets contains over 99 per cent. pure aluminum, generally running about 99·40 per cent. pure aluminum.

Special attention is given to the fabrication of aluminum alloys by the Pittsburgh Reduction Company, to avoid oxidation; and to this end, rich alloys are first made, to be afterwards reduced to their proper percentages by re-melting with pure aluminum. These rich alloys are made in the electrical pots or furnaces at the same time that the aluminum is made, in this way more thoroughly combining the metals than can possibly be done by melting them and mixing in crucibles, where their varying melting points render the oxidation from over-heating very liable to occur.

Cast aluminum can be very much improved in rigidity and tensile strength if afterwards subjected to the drop-forging process. For special light-running machinery, drop-forgings of nickel-aluminum casting metal are particularly well adapted.

One of the most promising uses of aluminum at the present time is in the fabrication of *aluminum cooking utensils.*

The lightness, difficulty of corrosion, ease of keeping clean, high thermal conductivity and comparatively high specific heat of the metal, make its use for cooking utensils particularly advantageous.*

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*That the Institute may know what the opinions of some of the large manufacturers of aluminum cooking utensils are, I quote from a letter of February 12, 1897, from the Griswold Manufacturing Company, Erie, Pa., one of the largest manufacturers of iron hollow-ware cooking utensils.

"It is about four years since we commenced to cast aluminum into cooking utensils. We began in a small way, and have continued with a constantly increasing demand ever since, until now the outlook for sales is exceedingly promising, and the amount that we reasonably hope to dispose of this year will be very large."

Similarly, I quote from a letter from the firm of Sidney Shepard & Co., Buffalo, N. Y., February 12, 1897, one of the largest manufacturers of stamped metal ware in the country:

"Aluminum cooking utensils are destined, as soon as the extreme hard times which have existed for the past two or three years are over, to meet with a very large sale, for the reason that those who have used them have, in almost every instance, expressed themselves very favorably in reference to them, and our trade has been considerable, notwithstanding the fact that the goods are now unappreciated and higher priced than other ware on the market."

And from the Hill-Whitney Aluminum Company, of Boston, Mass., also large manufacturers of aluminum cooking utensils, under date of February 24, 1897:

"Our cast aluminum tea-kettle business is increasing continuously, as people know the value of such a utensil, and we believe, in the general line of goods, there has been only a beginning."

Aluminum cooking utensils are made both in the form of cast hollow-ware and stamped or spun work.

Many attempts have been made to use soldered joints with aluminum cooking utensils; but in all cases these have proved unsuccessful because of the galvanic action set up between the aluminum and the metal of the solder, occasioning corrosion thereby. I shall refer to this point more fully under the subject of solders for aluminum, to be treated later on in this lecture.

In sheet-metal work of aluminum, relatively better results are obtained with stamped work. Aluminum can be spun as readily as almost any other metal; but it must be borne in mind that the metal is not only light in weight, but relatively to other metals, it is also open in texture. The spinning operation being of such character as to spread apart the particles of the metal, a much more open surface is presented for corrosion. While in many places, spun articles in cooking utensils, as in the tops of tea-pots and similar articles, are in every way all that can be asked of them, where an article can be as well stamped into shape it is always better practice to carry out this method of shaping the utensil.

The cast aluminum tea-kettle is certainly an improvement in household economy, of which every housewife who has used them can speak enthusiastically.

A complaint has been made of aluminum cooking utensils that they turn black by wear. This has sometimes been occasioned where the metal has been subjected to the action of sulphuretted hydrogen, and where the aluminum contained a sufficient amount of copper alloyed with it to form a black sulphide of copper on the surface of the metal; but by far the largest portion of this difficulty can be attributed to the action of ammonium salts, which gradually attack the surface of the aluminum, leaving behind a coating containing silicon, which, although rapidly attacked by concentrated alkali, resists very many solutions of organic matter, as well as moist or dry air. An aluminum surface which has thus been treated has a brown or blackish color. It is really a very serviceable way to treat the metal for a durable finish, to withstand corrosion; but it has occasioned complaint on the part of those who do not understand the phenomenon as being caused by impurities in the aluminum.

I have investigated several such cases, where only the purest commercial aluminum has been used, and have found that the discoloration referred to was of this surface coating of metallic silicon on the metal.

This action need occasion no anxiety on the part of users of aluminum cooking utensils, as there is no injurious action in the discolored coating, which may be removed by treatment of the aluminum with caustic alkali, doing this by rubbing the metal with a rag dipped in alkali in a way to avoid too serious corrosion of the aluminum. Care, of course, should be taken by one using caustic alkali not to burn or corrode one's hands, as well as the aluminum. With the exception of the looks, this coloration need cause no uneasiness, for there is no real detriment to the healthful use of an aluminum cooking utensil so discolored.

On the other hand, if simply boiling water in a pure aluminum cooking utensil causes this marked black discoloration of the metal, it is a serious indication that the water used is not above reproach, and it usually indicates that the water contains a considerable proportion of free ammonia in solution, which may be occasioned by contaminating sewage.

One of the great advantages of aluminum is that the salts which are occasioned by its corrosion are not in any way poisonous.

Aluminum can easily be kept free from corrosion by the same care that is bestowed on bright work of brass or other metals. In fact, with one-half the work required to keep brass work polished, aluminum can be kept with a nice polish.

Pure aluminum is not by any means as readily corroded as the alloys. The natural impurities of aluminum are silicon and iron, and both tend to render it more easily corrodible than the pure metal. With imperfectly made aluminum, metallic sodium is sometimes alloyed with the metal. Its presence occasions the rapid corrosion of the aluminum.

If the aluminum has been overheated in its molten condition, it is liable to occlude gases, especially nitrogen, which occasions an open, stoggy, porous metal, which is more easily corroded than pure aluminum.

Aluminum is receiving extended use *in chemical laboratories* for various apparatus, as in water-baths, air-baths, Bunsen burners, hot-water filtering funnels and in condenser tubes.

Prof. T. H. Norton, of the Chemical Laboratory of the University of Cincinnati, has just published in the *Journal of the American Chemical Society* an interesting article on "The Use of Aluminum for Condensers;" the condenser he used being described as follows:

"Outer jacket of glass, inner tube of aluminum, length 122 centimeters, external diameter 1 centimeter, inner diameter 8½ millimeters; weight per meter, 29 grams. At a distance of 15 centimeters from the end, the tube was bent at right angles, permitting connections with a distilling flask, without allowing the condensing vapors to come in contact with any substance but aluminum."

In bending an aluminum tube, Professor Norton recommends filling the tube with molten lead, when the temperature will be attained which allows the tube to be bent as desired.

Professor Norton experimented with organic liquids, alcohol, benzole, nitro-benzole, chloroform, ether, acetone, etc., and states that "very rapid distillations could be carried on with an exceedingly short tube, on account of the high conducting power of the aluminum. The residues obtained showed that there was practically no attack upon the aluminum."

"The deportment of the aluminum condenser toward steam was also carefully investigated; comparative experiments being made with glass and block-tin condenser pipes. The results showed that, so far as purity of the product was concerned, aluminum possessed about the same advantages as glass over tin, in connection with the distillation of water. In lightness and conductivity it exhibited marked superiority over tin."

These careful experiments made by Professor Norton, as well as many other tests made in a similar way by other chemists, have shown that pure aluminum is not corroded seriously by organic solutions or by ordinary water or steam.

My experience with cooking utensils and similar articles, where corrosion has occurred, is to the effect that the cause of the trouble can be traced back either to an excessive amount of hydrochloric acid or chloride salts, or to the presence of caustic alkali solution in contact with the metal.

All aluminum surfaces in utensils, after being wet, should be carefully dried off, if practicable, for with almost all forms of metal one of the most serious forms of attack is by alternate exposure to water, which is allowed to gradually evaporate or dry on the metal; the residues in the water occasioning dirt to settle upon the material and some little corrosion is occasioned on almost every form of metal.

As a Reducing Agent, the element aluminum is already receiving important use. I speak of aluminum as an "element" because it is now universally so considered, which means nothing more than an admission of ignorance on our part as to the possibility to further decompose it. Whether in the light of the knowledge of the next generation our descendants will classify the metal aluminum as an "element," is an open question. As for myself, I am inclined to doubt it.

On April 28, 1891, a patent* was issued to Prof. John W. Langley for the use of aluminum as a reducing agent, in the preparation of alloys of aluminum. He claims therein the "art of alloying aluminum with more electro-negative metals whose oxides or salts are difficult of reduction" by a method "which consists in incorporating such oxide or salt with a molten fluoride bath and then adding aluminum thereto."

At the same time, Professor Langley patented an alloy of aluminum and titanium,† also an alloy of aluminum, titanium and chromium,‡ both made in this manner, and both issued under date of April 28, 1891.

Drs. Greene and Wahl,* in 1891, began a series of investigations which resulted in the devising of a method of producing metals, free from alloying constituents, by reducing the oxides of these metals with aluminum. The purity of the products thus obtained depends on the purity of the oxides employed. By using an excess of the metallic oxide, it was found that no aluminum remained in the product. In this way, these investigators demonstrated that manganese, chromium and certain other metals, electro-negative to aluminum could be obtained from their oxides in a state of high purity by reduction with aluminum. The process was patented in the United States and foreign countries in 1893,[†] and has been applied commercially to the manufacture of manganese and chromium. The circumstance that the metals produced by this method, in addition to being practically free from alloying metals, are absolutely free from carbon, should render them of peculiar value in the production of special steels.

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*See U. S. Patent No. 451,404.

†See U. S. Patent No. 451,405.

‡See U. S. Patent No. 451,406.

*Garrison. *Trans. Am. Inst. Mining Eng.*, **21**, 887; Jour. Frank. Inst., **135**, 218.

Since that time, the noted chemist, Moissan, has called attention of the scientific world to the properties of aluminum as a reducing agent, for the difficultly-reducible metals, using aluminum in fine filings for the purpose. By a process in a general way similar to that suggested by Professor Langley, Moissan has prepared many of the rare metals and has improved on the process of Professor Langley in obtaining these metals in almost a state of purity; that is, with very little alloy of aluminum associated with them. The use of aluminum as a reducing agent is already a considerable one, and bids fair to be a growing business.

According to Moissan,[*] many alloys can be obtained by taking advantage of the ease with which metallic oxides are reduced by aluminum. The general method is to throw a mixture of aluminum filings and the oxide of the particular metal into melted aluminum. Part of the aluminum burns, and there is so energetic a development of heat that the most refractory oxides are reduced, the metal mingling with the excess of aluminum. In this way, alloys of aluminum with nickel, molybdenum, tungsten, uranium and titanium have been prepared. An alloy can be obtained containing as much as 75 per cent. of tungsten. The direct preparation of copper-chromium alloy is difficult, but an aluminum-chromium alloy is readily obtained in the manner indicated, and this dissolves in all proportions in fused copper, forming a copper-aluminum-chromium alloy, from which the aluminum is readily eliminated by stirring in cupric oxide, a copper-chromium alloy being left. A similar method can be applied for the introduction of tungsten and titanium into open-hearth steel.

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[*] U. S. Patent No. 489,303, January 3, 1893.

[*] *Comptes Rendus de l'Académie des Sciences*, **122**, 1302-1303.

Aluminum seems to be particularly adaptable *for surgical instruments and appliances*, and already considerable sale of aluminum has been made for such apparatus.

Aluminum is used for the *handles of surgical saws, knives* and similar tools and cases in which instruments are kept. Speculum instruments and similar apparatus are being largely made of aluminum.

Aluminum has also been used in tracheal instruments and metal appliances which are placed in contact with living tissues.

The particular advantage of aluminum for these uses is its lightness, and the fact that it is not corroded by carbolic acid and similar antiseptic reagents, which allows the metal to be readily cleaned by antiseptics.*

Aluminum has been used quite largely *for bicycle parts* during the past few years, and the business seems to be a growing one in this country. A bicycle, called the Lu-Mi-Num bicycle, has been placed upon the market and, as a specimen of casting, is really a fine piece of workmanship. The entire frame of the bicycle is cast in one piece, quite a number of the bars being hollow, in the form of tubes. The frame is cast in metal moulds, with flexible cores, which are removed after the casting is poured.

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*Mr. Will McConnell, of Claysville, Washington County, Pa., has an aluminum plate 4 inches long, placed in his jaw, to take the place of a part of the jaw bone. Dr. Louise J. Lisle, of the Presbyterian Hospital, Allegheny City, Pa., performed the operation, and it is proving in every way successful.

A considerable number of persons have aluminum in various parts of their anatomy where it is proving satisfactory; the more common use being being in *aluminum plates* in the mounting of false teeth and *dental work* of similar character. Certain professional dentists are making a specialty of aluminum mountings for false teeth, and there are quite a number of dental surgeons who use the metal more or less extensively in their practice. One important manufacturer in New York uses aluminum largely in the manufacture of *artificial limbs*.

The secret of the efficient work which is done in these castings, is the process invented by Mr. L. J. Crecelius, St. Louis, Mo., by which the metal is cast into iron moulds which have been heated to a red heat or about the temperature of the molten aluminum, before the aluminum is cast into the same. Large sinking-heads are provided and the metal is cooled from the bottom of the casting upwards, by blasts of air upon the outside of the metal mould, the metal in the "riser" being kept molten the longest and taking the shrinkage from the mould. As soon as the casting is cooled sufficiently, the mould, which is made in halves, is opened up and a perfect casting taken out of the mould.

Many special alloys have been used in the making of bicycle frames, handle-bars, etc. In Europe, there is at present a good deal of talk about an alloy called "Alcolite," which has been produced as the result of the experiments of Mr. Wm. Pearson, Birmingham, England. Another alloy which has received widespread advertisement in Europe is "Romanite."

These various alloys are simply pure aluminum hardened with a few per cent. (ordinarily less than 10 per cent.) of nickel, copper, titanium, manganese, zinc, tin and similar metals. The composition of these alloys can in all cases readily be told by chemical analyses. All of these alloys stand in relation to the metal aluminum as the various grades of steel are related to iron. The experience of the Pittsburgh Reduction Company with the alloying metals as hardeners is to the effect that copper and nickel, while hardeners to a certain extent, do not render the metal as hard as do many other alloying metals. They are advantagous to be used as carriers, permitting the proportion of the hardening material to be increased, and to give toughness and ductility to the product; but where extreme hardness is desired, zinc, manganese and titanium give much more efficient results, although all of these, unfortunately, render the alloy more brittle than does nickel or copper alone.

In Great Britain, the latest forms of aluminum bicycles do not have the frames made in one piece, but aluminum tubes are used, which are drawn on mandrels from hollow tube ingots and have the advantage of the worked metal over castings, in both strength and ductility.

These tubes are brazed by a secret process, and, by the use of the X-ray apparatus, are shown to be perfectly welded joints.

The Pittsburgh Reduction Company has also a considerable demand for aluminum to be used for cast aluminum brake-shoes for bicycles, as well as for aluminum sheet for rims. Aluminum mud- and chain-guards, both in cast and stamped metal work, are being made.

Aluminum has been used successfully for *lithographic work,* the light plates being used in place of the heavy and expensive lithographic stone which has been used in the past.

The Ellery-Howard firm, of New York, claims to have a patent on the surface printing from aluminum plates, with patents relating to certain rotary presses for the use of the aluminum plates.

A German firm also claims to have patents for surface-printing with aluminum plates. This firm uses in the work a flat-bed press instead of a rotary press.

The advantages claimed for the rotary press are that some 25,000 impressions per day can be obtained with a rotary press, where only 8,000 impressions can be obtained with a flat press. The number of impressions which can be taken with a rotary press depends principally upon the speed with which the printed sheets can be removed from the press. There is not room for more than three men to work around the mouth of the press, and 25,000 is about all they can handle, if the sheets are large.

Aluminum plates for lithographic purposes are grained as follows:

They are either sand-blasted, with a sand which is not too fine, or they are grained by placing them in a horizontal position in a sort of cradle with marbles about an inch in diameter, which come for the purpose of graining zinc plates, etc. These plates are rocked in this cradle with the marbles, sand

and water, in the usual way. After the plates have been either sand-blasted or grained, their surfaces are treated in order to remove any foreign matter, by first cleaning them with benzine, then dipping the plate in caustic potash, then into a solution of nitric acid, and washing in hot water. After this is done, the plate can be worked on with pen and ink, and will take impressions from a specially prepared transfer paper, which is used by lithographers.

In another lithographic process different from that just described, the aluminum plate is covered with a very thin coating of copper. The transfer is then put on with a prepared ink, which the acid does not attack. Then the plate is treated with an acid which attacks the copper and does not attack the aluminum. The copper is eaten away down to the aluminum and leaves a printing surface which really stands in relief like an electrotype. This process seems to have a promising future.

For letters and signs, aluminum has become quite extensively used, not only in the form of fine powder or bronze, but also in heavy cast aluminum letters, which can readily be attached to glass as well as to wood. There are several companies in the United States which make a specialty of this business, and I take pleasure in showing some specimens of this class of work.

Aluminum has not yet been used, but has been proposed in the fabrication of passenger coaches, for use both in the roof and sides of the car, as well as in the fittings around windows, etc. There is just now under consideration by one of the leading railroads of the country a proposition to build some cars along the line just outlined; and it is my opinion that in the course of a few years there will be a considerable use of aluminum in railroad passenger cars and their fittings.

A type of passenger coaches finished with copper on the outside in place of the usual paint and varnish, is being put into service on the New York, New Haven and Hartford Railroad. The advantage claimed is that the cars are more readily kept in condition of cleanliness and brightness, and when it is necessary to send a car to the shops for exterior overhauling, it is ready for the service again in half the time required to paint and varnish it. All the wood paneling and sheathing is made in precisely the same manner as at present, except a shade thinner, and a light coating of copper is formed around the wood, fitting closely into all curves and corners. Each piece of sheathing and its strip of copper are passed through the machine simultaneously and come out ready for use with the copper wrapped tightly around the wood. After the sheathing and other members are covered or plated with copper they are applied to the body of the car in such a manner that the exposed surfaces are not punctured by nails or other fastenings, so that when completed the casual observer would not notice but that the car was finished with paint and varnish. All joints are absolutely water-tight.

Only one car has thus far been finished in this way, and the copper on this car was oxidized, giving it a dark, glossy finish very similar to that of the ordinary Pullman coach. The next car will be put on the road without this, as the copper will oxidize in the atmosphere, attaining in a few days a deep rich bronze tint. No paint or varnish is used on the outside of the car, excepting on the roof, platform, hoods and window sash. The numbers and letters are made of cast aluminum and are attached by screws. It is also believed that the new copper-coated cars will improve in appearance with wear rather than be dulled by it, and the cost of cleaning and keeping the exterior in condition will be very materially reduced. If the car be injured, unless the copper is punctured or torn, it can be taken off, re-rolled and put on again. The weight of the car is not increased by this method of finishing; in fact, in the car just put into service the weight was lessened, owing to the wooden members having been thinned sufficiently to compensate for the difference in the weight of paint and varnish and that of copper.

It is evident that aluminum sheet can be advantageously used in the same way. The metal can be given a dull finish in many shades equally as well as can copper sheet.

Aluminum is now being used in metal appliances in street railway cars. For the handle-bars of these cars, there is a particular advantage in the use of aluminum over brass. In the summer time, when the conductors have to handle with perspiring hands the brass handles, the corrosion of the brass in many cases occasions sore eyes and affections of the mucus membranes, occasioned by the hands becoming impregnated with these copper salts.

Aluminum bronze-powders, as they are called in the trade, have almost entirely replaced silver bronze-powders. Aluminum bronze-powder is simply finely-powdered aluminum metal. In the best grades, it is pure aluminum thus prepared, but in the cheaper varieties, now largely sold in the markets, the aluminum powder is adulterated often with as much as 50 per cent. of tin powder. As pure aluminum corrodes less rapidly and is entirely unacted upon by sulphuretted hydrogen, it is more durable than silver powder, and the article adulterated with tin, and is therefore superior to them.

Aluminum bronze-powder is used as a paint on signs and bronze-printing work, as well as very largely for interior decorations.

Because of the extreme malleability and ductility of aluminum, it is preceded in the relative order of malleability of the metals by gold only, and in the order of ductility by gold, silver, platinum, iron, soft steel and copper. Both malleability and ductility are impaired by the presence of the two common impurities, silicon and iron. Aluminum of over 99 per cent. purity is rolled into sheets of only five to seven ten-thousandths of an inch in thickness, and such sheets are hammered into leaf nearly as thin as gold leaf can be beaten.

Aluminum leaf is largely used for decorative work, and on account of its relative cheapness and non-tarnishing qualities, it has almost entirely superseded the use of silver leaf. Aluminum leaf is ground up into powder and used in large quantities for the pigment of a decorative paint, called by the trade "aluminum bronze paint."

Painting with aluminum bronze is done in two ways:

(1) By thoroughly mixing a certain amount of bronze-powder with the varnish and applying with a brush.

(2) By varnishing the surfaces first and then, with a small

brush of raw cotton dipped in the bronze-powder and used as a powder puff, applying the powder.

By this latter way, all of the aluminum bronze-powder is located on the surface, and a brighter painted surface is obtained.

Aluminum has been used to harden rubber, in the vulcanizing process; also to give it a peculiar golden-yellow color.

Cast aluminum bath tubs, sinks and similar plumbers' supplies are now being made by the Western Brass Manufacturing Company, of St. Louis. I have in my own home a cast aluminum bath-tub and cast aluminum sink, both of which are giving excellent satisfaction. Both, however, require care in being washed clean from the soapy residue after use; but with such reasonable care as is ordinarily taken in keeping iron free from rust, these articles are giving excellent satisfaction.

Aluminum has been used quite extensively for *oil cups* and other parts of light-running machinery, where reciprocal motions are made and the momentum of the moving parts occasions considerable strain upon the material. In such cases, the lighter weight of aluminum has been of special advantage.

Aluminum, especially in forms where it is alloyed with a few per cent. of hardening ingredients, is now being used very largely *in castings of all descriptions,* where lightness, non-corrodibility, or a silver color is desired. The alloys most used in general castings have a tensile strength of about 20,000 pounds to the square inch, and are about one-third the weight of brass.

The same general method is followed as in making brass castings. Either iron or sand moulds can be used. The metal should be poured as cold as possible, in order to insure sound castings, free from blow-holes (caused by the very great absorption of gas by overheated molten aluminum), or cracks and depressions due to shrinkage. It is also desirable in most cases to use large gates and risers, as a further safeguard against these defects. The gate should be put in such a place on the casting that the metal will not "draw away" where the gate joins the piece. Particular care should be used for this reason in making "gated patterns."

The practice of some moulders is to immerse small quantities of nitre in molten aluminum to purify it, the oxidizing effect of this salt undoubtedly acting somewhat beneficially if care is taken to see that all of the potash salts are allowed to come to the surface and are skimmed off, to prevent contamination of the metal.

The method of adding nitre in foundry practice is as follows: After the metal is removed from the fire, and before pouring, slightly dampen a sheet of writing-paper with water. Put in this paper one tablespoonful of nitrate of potash to about 100 pounds of metal. After the nitrate of potash has been wrapped in this paper, it should be placed on the top of the molten metal, and instantly, with an iron ladle or stick, it should be pushed to the bottom of the pot. By the time it reaches the bottom the paper burns, and the nitre comes up through the metal, combining with the oxide as it comes to the surface. It is then skimmed off.

Charcoal is the best fuel to use in melting aluminum, and should be used in all cases where especially good castings are desired. Both coke fires and natural gas are successfully used in melting aluminum. Care should always be taken, not only to not overheat the metal but also to prevent the occlusion of gases in aluminum. Both nitrogen and hydrocarbon gases are especially liable to be absorbed by molten aluminum. Care should also be taken to have the flasks well vented.

Aluminum is melted in ordinary plumbago crucibles, such as are used for melting brass. If the metal be not overheated, it will absorb no appreciable amount of silicon from the crucible. Aluminum remelted twenty times in such a crucible showed only an addition of one-tenth of 1 per cent. of silicon.

Aluminum does not unite with or absorb carbon in any considerable quantity when heated in contact with it, unless the metal be heated much above its melting point.

The melting point of aluminum is 1,157° F., or 625° C. At about 1,000° F. the metal becomes granular and can easily be broken. [The melting point of copper is 1,929° F.; that of cast iron, 2,372° F.]

No flux is needed to cover aluminum, for it is non-volatile at any temperature that can be attained with any ordinary coke fire without blast. A very thin film of oxide forms on the surface of the molten metal, which, while not enough to injure either ingots or castings, protects the metal from further oxidation.

SHRINKAGE OF CASTINGS OF METALS.

	Inch to the Foot.
Pure aluminum ($\frac{13}{64}$ inch)	·2031
"Nickel Aluminum Casting Alloy" ($\frac{3}{16}$ inch)	·1875
"Special Casting Alloy" of the Pittsburgh Reduction Company, ($\frac{11}{64}$ inch)	·1718
Iron, small cylinders	·0625
" pipes	·125
" girders, beams, etc.	·100
" large cylinders, contraction of diameter at top	·625
" " " " " " " bottom	·083
" " " " in length	·094
Thin brass castings	·167
Thick brass castings	·150
Zinc	·3125
Lead	·3125
Copper	·1875
Bismuth	·1563

The use of *aluminum in the galvanizing bath* has become so universal that at the present time it is considered a necessity in order to produce the best and most economical work. It is added in the form of aluminized zinc, which is made according to a process devised and patented by Mr. Jos. Richards,* of Philadelphia, and a member of this Institute. This aluminized zinc is used in such proportions that the total amount of aluminum in the bath will be about 1 pound of aluminum per ton of bath, or in using a 5 per cent. aluminized zinc, 20 pounds of aluminized zinc per ton of bath should be used. These proportions, however, are varied according to the grade of zinc which is being used, and also upon the class of material to be galvanized. In some cases more, and in some cases less than the quantities given above will be found most advantageous.

When aluminized zinc is used, it has been found unnecessary to use sal-ammoniac, for clearing the bath of oxide, as the aluminum accomplishes the same purpose; and if the two are used together, they seem to counteract the effects of each other. Aluminized zinc should be added to the galvanizing bath gradually, and not all at one time; and as the bath is consumed, fresh aluminized zinc is added in the proportion of about 1 pound at a time, for a 5-ton bath. This is when a 5 per cent. aluminized zinc is used.

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*See U. S. Patent No. 456,204. July 21, 1891.

The first action of aluminum in galvanizing baths is to make the bath more liquid, which is one of the objects in adding the aluminum; a greater amount of aluminum seems to combine with the impurities in the zinc and come to the surface in the form of a scum, which makes galvanizing difficult. If, therefore, too much aluminum goes into the bath, the bath should be well stirred and allowed to stand for a while until the aluminum combines with these impurities and comes to the surface as a scum. The scum should then be removed, some sal-ammoniac should be added to counteract the effects of the aluminum and the proportion of the aluminized zinc added should be reduced. In starting with a new bath, it is especially important that these suggestions should be followed.

Aluminized zinc is made by first melting the aluminum in a plumbago crucible and adding thereto zinc in proportions necessary to form the alloy of aluminized zinc required—ordinarily, 5 to 10 per cent. of aluminum with the zinc is used in common practice.

Aluminum has been used quite largely in *improving the quality of brass castings.* Brass is a mixture of copper and zinc, as distinguished from the bronzes, which are alloys of copper and tin. The proportions commonly used in making brass are 66 parts copper, 34 parts zinc. It is customary in the manufacture of ordinary commercial brass to introduce from 2 to 5 per cent. of tin for the purpose of giving added strength and density.

The terms "high brass" and "low brass" are used in he trade, but apply only to rolled material. High brass is composed of 2 parts copper and 1 part zinc, being a light color. Low brass is composed of 75 to 88 per cent. copper and 25 to 12 per cent. zinc, and in color is considerably darker than high brass. In ordinary commercial practice, cheap brass is a very heterogeneous material, much of it containing lead and some iron alloyed with it, either accidentally or for the purpose of giving an additional weight of cheap metals.

Aluminum has been added to brass with advantage in giving a stronger alloy. It has been used in all proportions from one-tenth of 1 per cent. to 10 per cent.; and the best results have been obtained by introducing the aluminum in the form of aluminized zinc. This is added in the same manner as zinc is ordinarily introduced into the copper, and in such proportions as will give the requisite amount of aluminum in the brass mixture.

The effect of aluminum in brass, added in this manner, in small quantities of less than 1 per cent., is mainly to make the brass flow freely and present a smooth surface, free from blowholes. When used in these quantities, from one-half to one-third more of small patterns can be used on a gate than can be used without the presence of the aluminum, for this amount of aluminum gives the brass such additional fluidity as to cause it to run more freely in the moulds and to a greater distance; consequently more patterns can be used on a gate. In quantities of over about 1 per cent., the effect of the aluminum commences to be very perceptible, from the fact that it imparts to the brass additional strength, and this strength is increased directly as the percentage of aluminum is increased, up to about 10 per cent. One per cent. of aluminum in brass is very extensively used for electrical purposes, as it gives a brass casting free from pin-holes and of greater strength than can be secured otherwise, from the same grade of brass. It follows, therefore, that by the use of a small percentage of aluminum in brass, a cheaper grade of brass can be used to do the same work than would otherwise be possible.

In all cases, if maximum results are desired, care must be taken that only pure metals are used. In connection herewith, it should be clearly understood that much of the copper and zinc commonly used contains considerable amounts of impurities, and the nature of some of these impurities is such as to absolutely prevent the production of good alloys with aluminum. In all cases, we would advise intending purchasers to insist on being furnished with an analysis of the metal supplied, and for aluminum alloys, to exclude all containing more than one-fourth of 1 per cent. of iron, arsenic, or antimony, or more than two-hundredths of 1 per cent. of bismuth. Alloys should be poured at a low heat as soon as fluid.

It should be noted that the presence of aluminum in these alloys lowers the point at which they become fluid, and that they are fluid at lower temperatures than either gun-metal or ordinary brass mixtures; therefore the average brass founder is very liable to overheat them, and great care must be taken to prevent this.

To illustrate the great differences which occur in metals found in the open market, the following are given as analyses of metals, some of which are good and others worthless for making good alloys:

ANALYSES OF METALS.

	Best Copper.		Tough Copper.	Bad Copper.		Good Tin.	Bad Tin.		Good Zinc.	Poor Zinc.
Copper	99·861	99·84	99·67	98·04	98·02	—	—	—	trace	—
Tin	·0		—	—	—	98·60	95·55	95·80	·020	—
Zinc	·0	trace	—	—	—	—	—	—	99·656	98·76
Silver	·053	·061	—	—	—	—	—	—	—	—
Lead	·017	·0	—	—	—	·034	·567	3·04	·158	1·09
Bismuth	·0	·0	·015	—	—	—	—	—	·0	·03
Iron	·030	·0	·018	—	—	·09	·812	·714	·093	—
Nickel	·039	·05	—	—	—	—	—	—	—	
Arsenic	—	—	·177	1·27	1·40	—	—	—	trace	trace
Antimony	—	—	·0	—	—	trace	2·58	·121	·0	—
Sulphur	—	trace	—	—	—	—	—	—	·073	—
Oxygen	—	0·26	—	—	—	—	—	—	—	—

The use of aluminum in cheap ordinary brass mixtures has sometimes occasioned the complaint that the surface of the brass castings is made black by the addition of the aluminum. This is due to the sweating out of the lead from the brass mixture, which the impure brass has contained.

It is not advisable to use aluminum in brass which is to be dipped in acid, as the aluminum, even in small quantities, makes the metal withstand the action of the acid so completely that the dipping is not successful. For this reason brass, which is subject to corrosion, is found to withstand this corrosion much better if it contains a proportion of aluminum, up to, say, 10 per cent.

The main objection to the considerable addition of aluminum to brass is the increased shrinkage of the alloy occasioned by the use of the aluminum. This has to be provided for by pouring the metal not too hot and using large gates and risers.

Aluminum-brass has an elastic limit of about 30,000 pounds per square inch and an ultimate strength of 40,000 to 50,000 pounds, with an elongation of 3 per cent. to 10 per cent. in 8 inches.

The use of *aluminum-bronze* is gradually increasing, for purposes where a strong and dense metal is required.

On account of the difficulty of making sound castings, and especially in rolling ingot-slabs capable of turning out sound sheets, the business has grown much more slowly than the bright prospects claimed for the use of aluminum-bronze eight or ten years ago would seem to indicate.

It is necessary now in the preparation of rolling slabs of aluminum-bronze that each ingot shall be planed off on the top until sound metal is obtained below the blow-holes, which always exist on the surface of the castings. This planing of the metal is expensive, due to the hard, dense character of the metal.

In the manufacture of aluminum-bronze, the best results will be derived by following closely the following method of manufacture:

Both the copper and the aluminum should be carefully selected, and none but the purest "Calumet and Hecla Mine" or "Lake" copper should be used and the aluminum should be guaranteed to be at least 99 per cent. pure.

The copper should be placed in a plumbago crucible, and melted over a charcoal or coke fire; these being the best fuels to use. Next to charcoal or coke as a fuel for melting comes oil, and then natural gas or producer-gas. It is impossible to make satisfactory aluminum-bronze over an ordinary coal fire, for the reason that the copper will absorb the gases from the coal. The copper should be covered with charcoal to prevent as far as possible oxidation and the absorption of gases, as there is always the liability of a small amount of gases being present, even in using the fuels previously mentioned.

After the copper has been melted, and the time has arrived to introduce the aluminum, the crucible should be grasped with tongs in order to remove it from the fire instantly, and the percentage of aluminum which it is desired to add, dropped into the pot through the charcoal.

In large pots of bronze, the pot may be removed from the fire before adding the aluminum. As soon as the aluminum goes into the pot, the first action, to a certain extent, will be a cooling one, caused by the actual temperature of the aluminum; but as aluminum and copper form natural alloys (*i. e.*, combinations in atomic proportions), the aluminum, as soon as it is heated to its melting temperature, enters into combination with the copper, by which a large quantity of latent heat is set free (or made sensible) by the chemical union of the two metals, and consequently the temperature of the mass is raised. If the mixture be watched, one can tell as soon as union takes place, for the reason that the copper will become more liquid, and also turn a little brighter in color.

This occurs in an instant after the aluminum is introduced; then, if the crucible has remained on the fire, it should instantly be removed, the charcoal skimmed from the surface, and the metal, which is now aluminum-bronze, poured into moulds of any convenient size, keeping the liquid metal in agitation by constant stirring until it is poured, in order to insure that the aluminum is as well disseminated through the alloy as possible.

If these points are strictly adhered to, good castings can be produced.

After this aluminum-bronze has become cold, it should be re-melted and poured into moulds as desired, for the purpose of manufacturing finished castings. Aluminum-bronze is found to improve with each successive re-melting and casting, until this has been accomplished three or four times, for the reason that it seems to give the aluminum a better chance to become more freely disseminated, and form a more uniform alloy with the copper.

The amount of aluminum in aluminum-bronze varies from a few per cent. up to 10 or 11 per cent., depending on the purpose for which the metal is intended. The strongest mixture contains between 10 per cent. and 11 per cent. of aluminum. Beyond this point, the bronze is hard to work, and becomes brittle.

Aluminum-bronze can readily be soldered. In soldering this alloy no such difficulty is encountered as is found in soldering pure aluminum. The best method of soldering aluminum-bronze is to use pure block tin with a flux made from zinc filings and muriatic acid. It is well to "tin" the two surfaces before putting them together.

[*To be concluded.*]

PISTON PACKING RINGS OF MODERN STEAM ENGINES.

By Otto C. Reymann,
With Westinghouse Electric and Manufacturing Company, Pittsburgh.

I. Only a few years have passed by since, with adoption of the multiple expansion system, the capacities of steam engines have grown considerably. Units of more than 1,500 horse-power and even 2,000 horse-power are found quite frequently nowadays. Not only the rapidly increasing use of electricity demanded larger and more economical steam engines for the equipment of power and lighting stations, but also the wants of modern marine engineering grew. The advantages of the multiple expansion steam engines having been demonstrated once, manufacturers very soon centralized their power plants, and put in large units, thus doing away with a great number of small steam engines, generally distributed over the factory.

The principal feature of the multiple expansion system lies in the use of high-pressure steam, and consequently in the possibility of utilizing the benefits of a greater expansion. Taking in consideration that the capacity of an engine, besides other factors, is directly proportionate to the area of the piston and the mean effective steam pressure, it is evident that, retaining the same piston speed, either or both factors had to be increased in order to obtain an engine of larger output. Using steam of high pressure and pistons of larger diameter a greater strain is exerted upon the piston itself. Necessarily, this demands a heavier construction of the piston block and its packing rings.

Besides this, the working conditions are rendered much worse. Instead of slow-speed engines, for instance, the equipment of electric plants requires high-speed steam engines suitable for direct connection to dynamos.

Units of 1,500 to 2,000 horse-power running at 75 to 90 revolutions per minute are to-day's standard for work of this kind. The desire of cheapening the engines by cutting down the over-all dimensions offered an inducement for adopting higher piston speeds—little desirable, considering the piston weight and its increased oscillating mass. Especially of horizontal engines with the weight of the piston resting on the lower side of the cylinder is this true and constituted a serious objection to this type of engines. Not only that the piston block is more strained by a greater piston speed, but the packing rings are subjected to a greater wear also, since friction of surfaces depends mainly upon their smooth condition, the pressure exerted upon the surfaces and the rate at which they slide along each other. From this, it will easily be recognized that the pistons of modern high-speed steam engines have to work under unfavorable conditions. And yet the proper function of the piston and especially of the packing rings is of the utmost importance.

Let us investigate what the piston of a steam engine has to perform. Certainly it is more than offering the steam a surface to act upon and to move it back and forth, thus driving the crank shaft. Economy demands that this be done with as little waste of steam as possible, *i. e.*, the piston must be steam-tight, preventing the steam from escaping to the exhaust side. This task is a rather difficult one and is not always accomplished satisfactorily. Innumerable contrivances have been adopted, having this end in view. Modern practice in steam engineering, however, has settled on metal packing. Taking a theoretical standpoint, packing is superfluous; for a piston turned mechanically true and fitted to a perfectly cylindrical hole will be tight and does not require any packing. But, even should original workmanship be sufficiently good as to dispense with packing, subsequent wear will demand its use. Furthermore, the influence of not evenly distributed forces acting upon the piston results in uneven wear of the rubbing surfaces, not to speak of the fact that piston and cylinder are expanded unequally by the steam heat.

The packing now generally used for steam engines consists of metal rings carried in suitable grooves, which are turned in the circumference of the piston block. Consequently, the rings slide along the cylinder walls at the same speed as the piston; to assure a steam-tight fit, the rings must be pressed outward against the cylinder bore, thus producing friction.

Leaving quite out of consideration how much this friction amounts to, it is obvious that the power of the steam engine used up in overcoming this resistance is altogether lost. Prof. R. H. Thurston demonstrated that the work wasted in piston friction is the largest item of the total internal friction losses of a steam engine, next to the friction of the main bearings. Badly-fitting piston rings in many cases are the cause of an abnormal steam consumption, and here the absolute necessity of well-working piston rings expresses itself in many a pound of steam passing through the cylinder into the exhaust without doing its work.

The work lost by piston friction as well as by escaping steam due to leakage around the packing rings must bear on the efficiency of the whole machine, and it follows that the piston must be kept steam-tight with as little pressure exerted upon and by the packing rings as possible. If the pressure of the packing rings upon the cylinder walls could be varied, the most favorable working conditions combined with the highest efficiency of the steam engine would be attained.

The problem involved presents itself in the simple question: How are packing rings for steam pistons to be designed in order to exert a certain amount of pressure upon the cylinder walls?

Before answering this question, it will be necessary to dwell for a moment upon the different methods of securing a steam-tight piston employed in modern steam engineering.

II. As mentioned in the first chapter, modern practice has discarded all hemp packings and decided in favor of an elastic metal packing ring for use in steam cylinders. With packing rings a steam-tight joint can be maintained in three different ways, viz.: the packing ring is pressed outward toward the cylinder walls:

(1) By its own elasticity.

(2) By the pressure of the steam which finds access behind the packing rings.

(3) By especially provided springs.

Of these three methods the second is employed always. Necessary allowances in width of the grooves, gradually increased by unavoidable wear, enable the steam to pass through the narrow passage between the side walls of the groove and the ring behind it. The use of special springs, called packing springs, is a modification of the method named in the first place. Springs are necessary if the initial elasticity of the ring is not sufficient to guarantee a steam-tight joint. Either the ring may have such a form as to give no spring action at all, or the material employed may have little elasticity itself. Where packing rings are made of gun metal, for instance, a steel ring or springs may be placed inside the ring, in order to exert a uniform pressure all around it. Steel or cast iron have by far a greater elasticity, and especially the cast-iron rings are found to be superior to all others for durability and satisfactory wear.

In the case where packing springs are used the piston ring is turned of the same size or a certain amount larger in diameter than the cylinder bore. They are then divided at one point to allow the packing springs placed inside to expand them.

If the steam-tight joint depends only upon the elasticity of the packing rings, they are made in two different ways. If wrought iron or steel is chosen, the rings are drawn of a suitable cross-section to fit the grooves in the piston block and then are bent to the proper curvature by rollers.

Where cast rings are to be employed, they are not cast individually, but cut off a cylinder of the proper thickness and of sufficient length to yield the required number of rings. This cylinder is turned all over, either inside and outside, concentric or in such way as to give rings of varying thickness. Their outside diameter is turned a certain amount larger than the bore of the steam cylinder. Consequently, the packing ring would be too large and a portion of its circumference must be cut out, so as to allow the compressed ring to be introduced into the steam cylinder.

It is obvious that the reaction of the force which is necessary to compress a packing ring in order to introduce the piston into its cylinder, afterward expands the ring and presses it outward against the cylinder walls, aided by such steam pressure as comes behind it. From this follows that the pressure which can be exerted by a packing ring depends mainly upon its material, its outside diameter and cross-section, the form of its curvature being only essential for an even distribution of the pressure all around the circumference. The question arises then: How much pressure has a piston packing ring to exert in order to maintain a steam-tight piston?

Although this question cannot be answered thoroughly by calculation, since the working condition of a piston is the most essential and ever-varying factor, its importance was recognized early; and as a result the only way of solving this problem, viz.: by experiment, was tried successfully. As far as the writer's researches went, however, an application of the data thus gained upon theoretical calculations of the strength of piston packing rings could be found only for the Ramsbottom rings.

In the following chapters the writer will derive additional formulæ for those ring types generally used beside the Ramsbottom rings.

III. In the experiments carried out with the assistance of the writer,* rings taken from pistons for locomotive engines as used by the railroads in Germany were dealt with. These pistons carried originally bronze packing rings, which were faced with babbitt metal. As the elasticity of these rings was very small, they had to be expanded by springs placed inside. Owing to the heavy duty and severe shocks of the engines, in less than six weeks the babbitt metal was worn off, and the piston had to be taken out of the cylinder in order to adjust the packing springs or replace the rings altogether. This rather annoying and expensive work led to a trial of cast-iron rings, of sufficient elasticity as to dispense with special springs. At the same time a series of experiments was undertaken, in order to determine the proper shape and cross-section of these rings. Cast-iron rings, especially made for testing purposes, and similar to those which had been in use for some time, were tested as well as rings well worn out. Originally, these rings had been uniformly ¾ inch thick, the smallest ring being ¾ inch wide, and the larger sizes about 1¼ inches. Their outside diameter varied from 14 inches to 18 inches. The length of the cut in the circumference averaged about one-tenth of the ring diameter.

Two different methods were adopted in measuring the pressure a compressed packing ring exerts radially. *Fig. 1* shows the manner in which the rings were suspended during the first series of tests. By four cat-gut strings the ring was held in a horizontal position, the upper ends of the strings being firmly fastened at one point, while the other ends carried a weight P. From the figure it will be seen that the total pressure exerted upon the ring at points X is equal the sum of the horizontal components of P; namely,

$$\Sigma W_1 = 4\left(\frac{P}{2} \tan \alpha\right)$$

and if angle $\alpha = 45°$

$$\Sigma W_1 = 2 P$$

The required length of each string

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*The experiments were made, 1878, by Mr. Charles Reymann, then Superintendent of Motive Power of the Berlin-Hamburg Railroad in Germany.

$$l = 2\,r\,\sqrt{2} + h$$

By this method the ring pressure is measured directly, whereas in another series of tests an indirect method was employed. As illustrated in *Fig. 2*, the ring was placed in a loop formed by a piece of wire. The one end of the wire being fixed, the other was loaded until the ring was compressed to a diameter ($=2\,r$) equal to the bore of the steam cylinder.

Let us call W the weight which is required to close the ring to the required diameter $= 2\,r$, and let us designate with M the resisting moment of the cross-section at C opposite the cut, then

$$W\left(2\,r - \frac{t}{2}\right) = M$$

The thickness of the ring is generally small compared with its diameter, and we may neglect $\frac{t}{2}$ against $2\,r$ without material error for practical use, putting

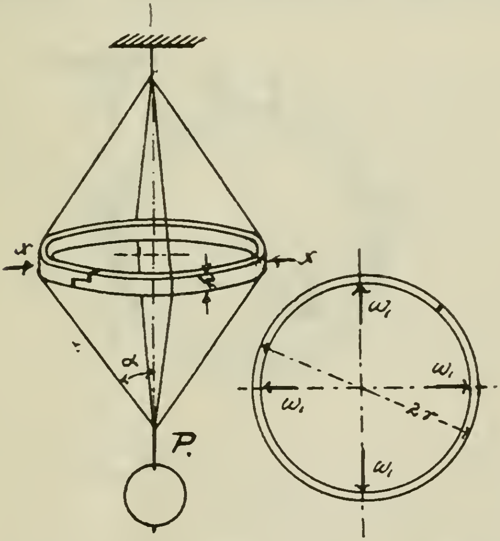

FIG. 1.

$$W = \frac{M}{2\,r}$$

If p, the pressure per square inch which results from the elasticity of the packing ring and acts radially outward, is constant for the whole circumference, the expanding force of the upper half, $A\ B\ C$, will be $= 2\ r\ h\ p$, and the bending moment at cross-section C

$$M = 2\ r\ h\ p\ .\ r$$

Since the load W is constant for the whole ring, we can substitute the value of M in the equation for W and write thus:

$$W = \frac{2\ r\ h\ p\ r}{2\ r} = h\ p\ r, \text{ or } p = \frac{W}{h\ r}$$

The depth h and the radius r being known and with W obtained by experiment, the unit pressure p can be calculated from the last formula.

It was found thus that p varied from 2¾ pounds up to 4½ pounds, in some cases, however, falling as low as 2¼ pounds. The greatest stress was reached at point C, opposite the cut, averaging 12,500 to 13,500 pounds per square inch. These rings only seldom broke, in spite of the heavy strain on them, a fact which speaks well for the quality of the cast iron used.

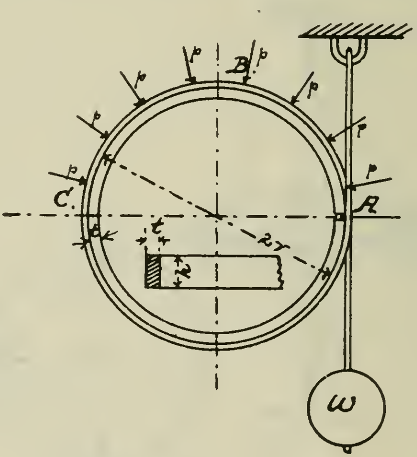

FIG. 2.

Upon an inquiry made by the writer concerning the strength of the cast iron used for packing rings by the Pennsylvania Railroad, Mr. Vogt, Mechanical Engineer of the Pennsylvania Railroad in Altoona, Pa., had made a number of transverse and tensile tests with different mixtures.* Cast-iron pieces originally 1⅜ inches square by 15 inches long, which were planed off as nearly as possible to 1 inch square, were used for the transverse tests. The tensile test pieces were turned down from 1⅜ inches round to 1 inch in diameter in an 8-inch section. The following table gives averages obtained from these tests:

Kind of Mixture.	Ultimate Tensile Strength.	Greatest Bending Stress.	Coefficient of Elasticity.
Machine Iron	18,000 lbs. per sq. inch	42,000 lbs. per sq. inch	12,800,000 lbs. per sq. inch.
Eccentric Iron	24,850 " " "	59,000 " " "	13,800,000 lbs. per sq. inch.

As will be noticed, the bending stress appears to be in both cases 2 1-3 times the stress for pure tension, the elastic limit of the eccentric iron being about 30 per cent. higher than that of the first mixture.

At the same time, Mr. Vogt tested several cast-iron packing rings of the parallel type, in order to ascertain the pressure exerted by them. The rings, of a standard pattern, as used by the Pennsylvania Railroad, were 18 to 20 inches in diameter, ½ inch wide and about ¾ inch thick, giving a p of 6 to 7 pounds per square inch. As the conditions under which these tests were carried out did not quite agree with those met in actual service, it appears to the writer that by making proper allowances for the superior quality of the material in these rings, Mr. Vogt's results harmonize well with those obtained by the writer.

Taking in consideration that these data were obtained from packing rings which had performed their duty satisfactorily under unfavorable conditions a pressure of 3 to 4 pounds per square inch exerted by the ring upon the cylinder bore can be considered sufficient to guarantee a steam-tight piston.

IV. *The Parallel or Ramsbottom Ring.*—The parallel ring is the simplest type of piston packing rings, having a uniform cross-section all the way through. It is either drawn of a suitable section and bent in rollers to the proper curvature, if made of wrought steel, or it is cut off a cast cylinder of sufficient length, properly finished. At one point the ring is divided by cutting out a piece of its circumference. The length of this cut depends upon the difference between the outside diameter of the free ring and the bore of the steam cylinder, which the compressed ring has to fit. The two ends are generally shaped in such a way as to prevent the steam from leaking through the cut after the ring has been sprung into its groove in the piston block; a lapped joint is shown in the accompanying sketch, *Fig. 3*. As no special springs are used for pressing the ring outward against the cylinder bore, the elasticity of the material alone is depended upon in securing a steam-tight joint.

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*The writer avails himself of this opportunity to thank Mr. Vogt for his valuable information.

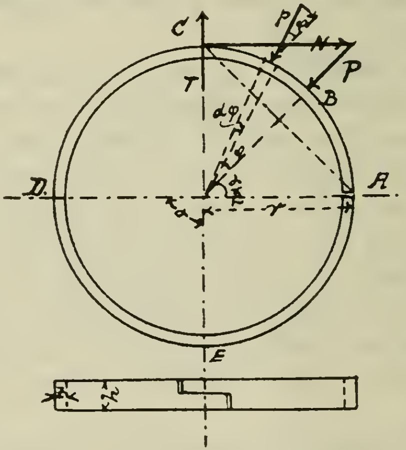

FIG. 3.

The pressure *p* thus exerted by the compressed ring acts radially and produces a bending moment in the packing ring. In order to determine its value we consider the ring fixed at point *C*, *Fig. 3*, and uniformly loaded with a pressure *p*. The resultant of the forces acting upon the arc *A B C* may be represented by *P*.

The pressure one ring element has to bear is $p\ h\ r\ d\ \varphi$.

Its component parallel to the resultant *P* is $p\ h\ r\ d\ \varphi\ cos\ \varphi$, while $p\ h\ r\ d\ \varphi\ \sin\varphi$ acts in a direction normal to P. The sum of these components for the quadrant $A\ B\ C$ is expressed by

$$2\int_0^{\frac{a}{2}} p\ h\ r\cos\varphi\ d\ \varphi\ (1) \text{ and } 2\int_0^{\frac{a}{2}} p\ h\ r\sin\varphi\ d\ \varphi\ (2)$$

respectively. Equation (2) must be equal to zero, since the components acting upon the arc $A\ B$ are equal to those acting on $B\ C$, but of opposite sign. Therefore equation (1) represents the value of the resultant P and we get finally

$$P = 2\int_0^{\frac{a}{2}} p\ h\ r\cos\varphi\ d\ \varphi = 2\ p\ r\ h\sin\frac{a}{2} \qquad (3)$$

The bending moment acting on cross-section C is equal to

$$M = P\ r\sin\frac{a}{2}$$

or substituting for P its value from equation (3)

$$M = 2\ p\ r^2\ h\sin^2\frac{a}{2} = p\ r^2\ h\ (1 - \cos a) \qquad (4)$$

The normal forces $(= N)$ and the shearing forces $(= T)$ are easily determined by resolving P as shown in the diagram (*Fig. 3*). Their values are

$$N = P\sin\frac{a}{2} = p\ r\ h\ (1 - \cos a)$$

$$T = P\cos\frac{a}{2} = p\ r\ h\sin a.$$

In these formulæ angle is the only variable factor. Therefore, in order to calculate the stress in any cross-section, the proper value for a has to be substituted in above formulæ. For various points we have the following values:

TABLE I.

At Point.	a	$(1 - \cos a)$	$M =$	$N =$	$T =$
A	0°	0	0	0	0
B	45°	·3	$\cdot 3\ p\ r^2\ h$	$\cdot 3\ p\ r\ h$	$\cdot 7\ p\ r\ h$
C	90°	1	$p\ r^2\ h$	$p\ r\ h$	$+ p\ r\ h$
D	180°	2	$2\ p\ r^2\ h$	$2\ p\ r\ h$	0
E	270°	1	$p\ r^2\ h$	$p\ r\ h$	$- p\ r\ h$
A	360°	0	0	0	0

This table shows that the maximum bending moment occurs at point D opposite the cut, where $\alpha = 180°$, and as the normal forces N reach their maximum at the same time, the combined stresses in this cross-section must be considered in dimensioning the packing ring.

From the condition that the external pressure p producing the bending moment M and the internal stresses acting on the same cross-section shall be in equilibrium, we have the relation

$$M = R\, f_b$$

For a rectangular cross-section is the moment of resistance

$$R = \frac{h\, t^2}{6}$$

and hence

$$f_b = \frac{6\, M}{h\, t^2}$$

The intensity of direct strain resulting from the normal stress N equals

$$f_s = \frac{N}{h\, t}$$

and therefore the combined strain at point D according to Table No. 1:

$$f_{\max} = f_s + f_b = \frac{2\, p\, r}{t}\left(1 + \frac{6\, r}{t}\right)$$

Neglecting the first member the formula may be written

$$f = 12\, p \left(\frac{r}{t}\right)^2 \qquad \text{(A)}$$

giving results sufficiently close for practical use.

So far the formulæ were derived with the assumption that the curvature of the ring is not changed by compressing it, in order to introduce the piston into the cylinder, *i. e.*, $r =$ constant. This condition, however, is not fulfilled with the Ramsbottom packing ring, as the outside diameter of the free ring is greater than the cylinder bore, and becomes equal to r only after the piston with the rings has been placed in the cylinder.

Let *Fig. 4* represent a part of the free ring, then if $P\,Q$ and

$P' Q'$ are two normal sections at a small distance apart, $C G = \rho$ is the radius of the unstrained ring. Through the influence of the bending moment M the particles originally in $P' Q'$ will be found in a new plane $P'' Q''$ still normal to the axis of the ring and their radius of curvature will now be $C' G = r$. As a consequence the fibers on the outer side are stretched and those on the inner side compressed. Owing to the qualities of the materials used for packing rings only the stresses which expand the fibers need be considered. Then a layer of fibers ($= h\, d\, y$) at a distance y form the neutral axis, the length of which was

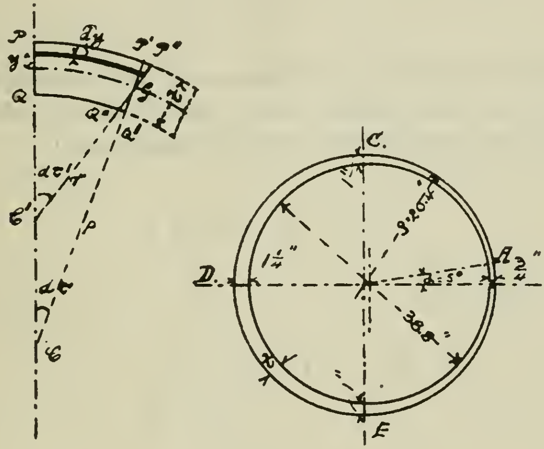

FIG. 4.

originally $(\rho + y)\, d\tau$ has been stretched to $(r + y)\, d\tau_1$, its elongation being

$$(\rho + y)\, d\tau_1 - (\rho + y)\, d\tau = y\,(d\tau_1 - d\tau)$$

Now the elongation λ of a uniform bar of the length L and the cross-section q is directly proportional to the stress P; the resulting unit stress thus $\frac{P}{q}$ is expressed by the well-known formula

$$\frac{P}{q} = \frac{\lambda}{L}\,\mathrm{E} = f$$

E representing the modulus of elasticity of the material. Substituting the proper values for L and λ we get as unit stress in a fiber at a distance (y) from the neutral axis:

$$f = E\,\frac{y\,(d\,\tau_1 - d\,\tau)}{(\rho + y)\,d\,\tau}$$

or since

$$\rho\,d\,\tau = r\,d\,\tau_1$$

$$f = E\,y\,\frac{\left(\frac{1}{r} - \frac{1}{\rho}\right)}{\left(1 + \frac{y}{\rho}\right)} \tag{5}$$

Equilibrium requires that the moment of the external forces equals that of the stresses acting on the same cross-section, therefore integrating for the whole cross-section:

$$M = \int_{-\frac{t}{2}}^{+\frac{t}{2}} f\,h\,d\,y\,y$$

or with equation (5)

$$M = E\,h \int \frac{\frac{1}{r} - \frac{1}{\rho}}{1 + \frac{y}{\rho}}\,y^2\,d\,y \tag{6}$$

For larger rings the fraction $\frac{y}{\rho}$ may be neglected without material error, thus putting

$$M = E\,h\left(\frac{1}{r} - \frac{1}{\rho}\right)\int y^2\,d\,y$$

and remembering that $\int y^2\,d\,y$ represents the moment of inertia for a rectangular cross-section $= I$, equation (6) takes the form of

$$M = E\,I\left(\frac{1}{r} - \frac{1}{\rho}\right) \tag{7}$$

(*To be Concluded.*)

Mining and Metallurgical Section.

Stated Meeting, June 9, 1897.

MR. BENJ. S. LYMAN, President, in the chair.

MONAZITE.*

BY H. B. C. NITZE, E.M.,
Chemist to the Wetherill Concentrating Co., South Bethlehem, Pa.

It has only been within the past few years that monazite has become one of the important economic mineral products, in its use for the manufacture of the incandescent mantles of the Welsbach light. Previous to that time it was considered one of the rare minerals, as denoted by its name, a derivation from the Greek, meaning "to be solitary."

The demand created by the manufacturers of the incandescent gas lights for the rare earth minerals stimulated the search for monazite, and it was soon found to exist in certain deposits and rocks, where its presence had not before been suspected, and so necessity became the mother of discovery.

Monazite is essentially a phosphate of the rare earths, cerium, lanthanum and didymium (Ce. La. Di.) PO_4. It also contains, almost always, small variable percentages of thoria (ThO_2) and silica (SiO_2), which by some are supposed to be present in combination, as an impurity, in the form of thorite or orangite ($Th.SiO_4.H_2O$), while others believe that the thoria is a primary constituent, present originally as the phosphate, either in combination with cerium or as an isomorphous compound, and afterwards altered to the silicate by siliceous waters.

Several typical analyses, made by Prof. S. L. Penfield,* of Yale University, are appended:

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*This paper embodies the results, in somewhat condensed and rearranged form, of previous communications by myself, which have appeared in the Sixteenth Annual Report of the United States Geological Survey, 1894-95, Part IV, and in Bulletin No. 3 of the North Carolina Geological Survey, 1895.

*See *American Journal Science*, Vol. XXIV, 1882, p. 250, and Vol. XXXVI, 1888, page 322.

	1.	2.	3.	4.
P_2O_5	28·18	29·28	26·12	29·32
Ce_2O_3	33·54	31·38	29·89	37·26
La_2O_3	28·33	30·88	26·66	31·60
ThO_2	8·25	6·49	14·23	1·48
SiO_2	1·67	1·40	2·85	0·32
H_2O	0·37	0·20	0·67	0·17
	100·34	99·63	100·42	100·15

(1) From Portland, Conn. (2) From Burke County, N. C. (3) From Amelia County, Va. (4) From Alexander County, N. C.

Monazite crystallizes in the monoclinic system. The usual crystal habit is tabular, parallel to the orthopinacoid ($\infty P\bar{\infty}$); also short columnar, and sometimes elongated in small needle-shaped crystals, in the direction of the prism (∞P). The crystals are usually well developed and free from distortion. They vary in size from microscopic needles, having a thickness of only 0·00015 to 0·00062 inch, to the abnormally large and rare crystals that have been found in Amelia County, Va., 5 inches in length. The more usual size, however, lies between 0·05 and 1 inch.

The cleavage is most perfectly developed parallel to the basal pinacoid (oP); it is also distinct, as a rule, parallel to the orthopinacoid ($\infty P\bar{\infty}$), and sometimes parallel to the clinopinacoid ($\infty P\grave{\infty}$).

The mineral is brittle, with a conchoidal to uneven fracture.

The hardness is 5 to 5·5. The specific gravity varies from 4·6 to 5·3. The luster is resinous to waxy, and the crystal faces are splendent in the fresh, pure specimens, and dull in the weathered, impure specimens, the surfaces being sometimes coated with a light brown earthy substance, probably an alteration product.

The purest specimens are transparent, becoming translucent and even totally opaque in the impure varieties.

The color is honey-yellow, amber-yellow, yellowish-brown, reddish-brown and sometimes greenish-yellow.

Monazite is an accessory constituent of the granitic rocks and their derived gneisses. It has been found in these rocks over widely separated regions of the earth's surface, and further search and study is liable to reveal its probable universal presence in most granites and gneisses. It has also been found in apatite, cyanite, and even in vein quartz. The main constituents of the granitic rocks (quartz, feldspar and mica) all contain the monazite as intergrowths, though it appears to be more generally confined to the feldspar. Zircon may be regarded as a constant accessory, and among the other usually associated minerals may be mentioned garnet, rutile, ilmenite, magnetite, xenotime, fergusonite, gadolinite, sphene, cassiterite, corundum, etc.

Monazite has not been found in the sedimentary rocks, although it may be present in some of these as a re-deposited mineral.

The economically valuable deposits are found in the placer sands of streams and rivers, in the irregular sedimentary sand deposits of old stream beds and bottoms, now covered up, and in the beach sand deposits along certain seashores.

In the Southern, unglaciated countries the decomposition and disintegration of the crystalline rocks, the original source of the mineral, have proceeded to considerable depths. By erosion and secular movement the loose material is deposited in the stream beds, where it undergoes a natural process of sorting and concentration, the heavy minerals, and among them the monazite, being deposited first and together. The richer portions of these stream deposits are therefore found near the head-waters.

The beach sand deposits have a similar explanation, the concentration in this case being brought about by the action of the waves.

The geographical areas over which such workable deposits have been found up to the present time are quite limited in number and extent. In the United States the placer deposits of North and South Carolina stand alone. This area comprises about 2,000 square miles, situated in Burke, McDowell, Rutherford, Cleveland and Polk Counties, North Carolina; and Spartanburg, Greenville and York Counties, South Carolina.

The country rocks are granitic biotite gneiss and dioritic hornblende gneiss. Most of the stream deposits have been worked for gold. The thickness of the gravel beds is from 1 to 2 feet, and the width of the mountain streams in which they occur is seldom over 12 feet. The percentage of monazite in the gravel is very variable, from an infinitesimal quantity up to 1 or 2 per cent.

In Brazil extensive deposits of monazite occur in the beach sands along the sea coast. The largest of these is on the island Alcobaca, in the extreme southern part of the province Bahia.

Deposits are also found in the gold and diamond placers of the provinces Bahia (at Salabro and Caravellas), Minas Geraes (at Diamantia), Rio de Janeiro and Sao Paulo.

In the United States of Colombia deposits of importance are reported in the gold placers of the Rio Chico, at Antioquia.

In Russia the mineral is found in the Bakakui placers of the Sanarka River in the Ural Mountains; also in the placer mines of Siberia.

In North and South Carolina the monazite is won by washing the sand and gravel in sluice boxes with a stream of water, exactly after the manner that placer gold is worked. The sluice boxes are generally about 8 feet long by 20 inches wide by 20 inches deep. Two men work at a box, the one charging the gravel on a perforated plate fixed in the upper end of the box, the other one working the contents up and down with a gravel fork or a perforated shovel in order to float off the lighter sands. The boxes are cleaned out periodically, depending on the richness of the gravel and the consequent degree of accumulation of the concentrated monazite.

From 40 to 70 pounds of cleaned monazite per box is considered a good day's work.

Sometimes two or more boxes are used, arranged in a series of steps, one below the other.

Magnetite, if present, is eliminated from the dried sand by treatment with a large hand magnet. Many of the heavy minerals, such as zircon, garnet, rutile, ilmenite, etc., cannot possibly be completely eliminated by any means of water separation, owing to the slight differences of their specific gravities.

The commercially prepared sand, therefore, after washing, is not absolutely pure monazite. A sand containing 65 to 70 per cent. monazite is considered a good quality.

Some operators endeavor to clean the water-concentrated sand still further, by pouring it, after it is dried, from a small spout situated in the bottom of a hopper, in a fine steady stream from a height of about 4 feet, on a level platform; the lighter particles (quartz, feldspar, etc.), together with the finer grains of monazite, garnet, rutile, etc. (which might be called tailings), fall on the periphery of the conical pile, and are constantly brushed aside with hand-brushes; the tailings are afterwards re-washed. Instead of pouring and brushing, the material is sometimes treated in a winnowing machine similar to that used in separating chaff from wheat.

Although the grade of the sand may in this way be brought up to 85 per cent. pure, the quantitative proportion is small as compared with the second and other inferior grades, and there is always a considerable loss of monazite in the various tailings.

It is impossible to conduct this washing operation without loss of monazite, and equally impossible to make a perfect separation of the garnet, rutile, ilmenite, etc., even in the best grades. The additional cost of such re-treatment and re-handling must also be taken into consideration.

A marked improvement in the economy and perfection of the treatment would be to size the raw material, separate the quartz and lighter minerals by jigging, and subsequently separate the heavy minerals, garnet, rutile, etc., in the jig concentrates, by passing over a Wetherill magnetic separator.* Experimenting in this direction, I have succeeded in making a practically perfectly clean monazite product, with but an insignificant loss in the tailings.

If the raw material contains gold, it will be collected in the sluice boxes or in the jig concentrates, and it may frequently pay to separate it, which can be readily accomplished by treating the wet concentrates in a riffle box with quicksilver.

The monazite in the stream beds of the Carolina fields has been practically exhausted, and the last mining operations were carried on, for the most part, in the old gravel deposits

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*See *Jour. Frank. Inst.*, **143**, 279.

and channels of the adjoining bottom-lands. These deposits are mined by sinking pits, about 8 feet square, to the bed rock, and raising the gravel by hand labor to sluice boxes above. The over-lay, which may vary from 3 to 5 feet in thickness, is thrown away, excepting in cases where it carries any sandy or gritty material. The pits are carried forward in parallel lines, separated by narrow tailing banks, similar to the method pursued in placer gold mining.

It has been shown that the monazite occurs in place as an accessory constituent of the country rocks, and that the latter are decomposed to considerable depths, sometimes as much as 100 feet. However, on account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work it for monazite alone, by such a process as hydraulicking and sluicing, for instance. Where the decomposed rock is gold-bearing, and this is sometimes the case, it may pay to recover the monazite as a by-product. In certain instances the decomposed gneiss, *in situ*, has been found sufficiently rich in monazite to warrant working it.

The value of monazite depends on its percentage of thoria, as this is the element mostly sought after by the incandescent light manufacturers. And, as the percentage of thoria is variable in different sands, the value of the sands is consequently also variable.

The only method for determining the percentage of thoria is by chemical analysis. The fluctuation of the thoria is considerable even in the same locality. It also depends, of course, in a measure, on the degree of concentration of the sand. Some monazite contains practically no thoria. The best Carolina grades carry from 4 to 7 per cent.

The price of Carolina monazite has varied from 25 cents per pound in 1887, to as low as 3 cents for inferior grades and 6 to 10 cents for the best grades, in 1894 and 1895. In 1896, the price fell so far below this mark as to render the mining unprofitable and practically cripple the industry. This was owing to the development and increased output of the Brazilian field, where the sand occurs naturally concentrated on the beach, and requires no cleaning treatment for shipping, after it is dug out. Being loaded directly into the ships' holds as ballast and transported by water, the freight costs are also considerably less.

In 1893, the output of Carolina monazite sand was 130,000 pounds; in 1894, 546,855 pounds; in 1895, 1,900,000 pounds; and in 1896, for reasons above named, it fell to 17,500 pounds.

CHEMICAL SECTION.

Stated Meeting of April 20, 1897.

DR. JOSEPH W. RICHARDS, President, in the chair.

THE CHEMISTRY OF FOOD ADULTERATION.

[ABSTRACT.]

BY HENRY LEFFMANN.

In addressing an audience of professional chemists, I feel that I must deal with this topic from a laboratory point of view only. General considerations would be out of place, as would also be any discussion as to the extent and effect of food adulteration or the legislation needed to limit it.

A marked tendency of modern analytic chemistry is toward uniformity of method. In certain departments this has been brought to a high degree of perfection, the routine of analysis having been developed with much detail, and hence a satisfactory uniformity of results will be attained by different chemists. In many of the departments of food analysis such uniformity has not been secured, and hence differences of results are not infrequent. I may note, however, a special cause of confusion, namely, the uncertainty of standards of purity. In many of the industrial applications of chemistry the analyst has no duty except to state the results in technical form. The interpretation of the data may be left to those to whom the report is made. In sanitary chemistry, however, there may be a wide margin for "inferences," and two chemists may differently interpret the same analytic figures. Sometimes an arbitrary rule is established either by the influence of some especially prominent scientific authority, or by official, *i. e.*, legislative, decision. These points are well illustrated by the now numerous laws applicable to milk adulteration. Not only are the methods of analysis somewhat variable, but an attempt also is made to fix an arbitrary standard below which all milk shall be deemed to be adulterated. This standard is not the minimum, as found by comparison of a large number of samples, but is fixed above that, under the assumed right to encourage the production of a high-grade article. Moreover, when milk analyses are reported it is not uncommon to affix a calculation of the "added water." This is based on a purely arbitrary assumption, namely, a minimum limit of solids—not fat. I contend that no chemist is justified in such an assumption. When a statement is made in court to the effect that a milk sample showed "10 per cent. of added water," the jury and all persons not familiar with milk analysis are led to believe that the water has actually been detected as such, whereas it is merely an arithmetic inference based upon an arbitrary assumption. Actual experience shows that in many cases milk just as taken from the cow would show a considerable percentage of "added water" by the methods of calculation now in vogue. The object of chemistry is the ascertaining of facts, not the encouragement of the breeding of high-class cattle.

A minuteness of routine is often needed to secure uniformity and comparability of results, but this minuteness must be more than a mere form. In some cases attention to minute detail is prescribed, although the processes are inherently approximate only. Such criticism, for instance, may be brought against the "official process" for the determination of the volatile acids in fat. The total amount of volatile acids cannot be obtained by the method, and the percentage present in normal samples of butter varies within wide limits. The practical purpose for which this process is used, namely, the detection of the admixture of foreign fats with butter, can be attained with certainty without the minute routine prescribed and the variations in normal butter far exceed the errors of experiment, even when the process is conducted somewhat roughly.

Another important point is the want of uniformity in the statement of results. Some of the data in analytic statements are not infrequently obtained indirectly, or by difference, and these facts should be in some way indicated in the report. In a State official report published some years ago, a list of many analyses of iron ores is given, the figures in each analysis adding up to exactly 100. It is obvious that some ingredient was determined by difference, yet there is no indication of this in the tables. In a neighboring State, reports on milk analysis are frequently made, which give separate figures for the fat, sugar, proteids and ash, and no information is given as to which of these ingredients are determined directly. If any ingredient is determined by difference, it should be stated; on the other hand, if all had been determined directly, there should have been a special determination of total milk solids as a control.

In water analysis there is much to be criticised, as regards the methods of stating results. Water analysis differs from most other analytic work, in that the results are never expressed in percentages, and hence has arisen much variety and irregularity of statement. At the present day, four forms of statement are used: grains per United States gallon, grains per imperial gallon, parts per million, and parts per hundred thousand. Some chemists, in the United States and England, use two methods in the same analysis, stating most of the ingredients in grains per gallon, but using parts per million (or per hundred thousand) for the so-called "ammonias." This is highly absurd, and it is surprising that anyone should adopt it. Its perpetuation is doubtless largely due to slavishly following Mr. Wanklyn, whose work in this field has been a curious medley of the ingenious and preposterous. When a statement of an analysis of water contains such data as sulphuric acid, carbonic acid, phosphoric acid or nitric acid, there is a vagueness which will closely interfere with a close calculation of results. Does the chemist mean by sulphuric acid, SO_3, SO_4 or H_2SO_4? Similarly, does carbonic acid mean CO_2, CO_3 or H_2Co_3?

The main object of furnishing the actual figures of a water analysis is to place on record the facts and to permit of the formation of an independent judgment, and it is in this light that we must proceed when we frame a method of statement. There is no reason why our methods of statement should not conform to the highest requirements of modern theories. It is often impossible and generally difficult to determine exactly how the various elements constituting the mineral residue of water are combined. Chemists follow certain conventional methods, based on probable controlling affinities, each case being in a measure decidedly independent, but in fairness these statements ought to be accompanied by information that the arrangement is largely supposititious. The proper way is to give a list of the individual elements or radicals, and thus permit any one familiar with the subject to re-calculate the data as deemed advisable. I consider it highly inadvisable to state any element in terms of a combination that cannot possibly exist in the water. We see much incongruity in reporting the very important data of the various conditions in which nitrogen exists in water. This element may occur in water in five states, namely, free and as nitrite, nitrate, ammonium and so-called organic compounds. The free nitrogen has little significance. Many valuable inferences may be drawn by the proper estimation of the last four forms. The brilliant work of Mr. Wanklyn has given a world-wide prominence to the last two data, and has fastened upon them two highly inappropriate titles. The nitrogen existing as ammonium compounds he called "free ammonia," which it is not; and the nitrogen obtained by his method from the organic matter he called "albuminoid ammonia," an equally inaccurate term. A still more absurd system has frequently been adopted for expressing the oxidized nitrogen; that is, that existing as nitrites and nitrates. The probability is that calcium nitrite and nitrate are the forms of combination usually present, certainly the acids themselves do not exist as such. Yet it is not uncommon to see the oxidized nitrogen expressed in terms of nitrous and nitric acid, which is as ridiculous as if a chemist would report the carbon in steel in terms of carbonic acid, or the silver in an ore in terms of silver nitrate.

The proper method of expressing the data of a water analysis is in terms of the elements and ascertained radicals present.

This commits the chemist to no theory, but allows any one to recalculate the data according to conventional methods of individual preference. Such a plan has the advantage of presenting the combined nitrogen so as to permit immediate judgment as to the ratio between the different conditions, a point that is of especial advantage in tabulating comparative results.

Uniformity in methods of analysis is highly desirable, but it is difficult to secure the consent of all chemists to some processes. A partial benefit will be gained if the methods are indicated in some manner in the report.

Stated Meeting of May 18, 1897.

NOTES ON THE DETERMINATION OF INSOLUBLE PHOSPHORUS IN IRON ORES.

[ABSTRACT.]

By Charles T. Mixer and Howard W. DuBois.

The authors referred to the greater necessity than formerly of determining the insoluble phosphorus in Bessemer iron ores, owing to the increasing demands for a lowering of the phosphorus content in what are considered standard Bessemer ores.

The usual method of fusing the insoluble residue with sodium carbonate has been found impracticable where a large number of determinations are to be made daily.

Experiments were instituted to devise a shorter method that would give accurate results.

The use of hydrofluoric acid to dissolve the siliceous residue from the acid treatment of the ore was found to be of no advantage as regards economy of time.

A mixture of ore and sodium carbonate subjected to a red heat (without producing a fusion) gave fair results with low silica ores, but was not adapted to high silica ores on account of the fusion of the mass.

Calcined magnesia mixed with the ore and ignited to a red heat (without fusion) extracted all the phosphorus, even with high siliceous ores.

Calcining the ore (without the admixture of any base) gave perfectly accurate results.

The calcination of the insoluble residue was just as satisfactory, so this treatment was adopted.

The details of the method are as follows: About 1½ grams of ore are dissolved in a No. 3 beaker with 25 cubic centimeters of hydrochloric acid, 1·1 specific gravity. When the ore is dissolved the excess of acid is evaporated until the solution begins to assume a syrupy consistency. It is then diluted with water and filtered into an Erlenmeyer flask, and the filter-paper and residue are placed in a platinum crucible and ignited. When the paper is burned off the residue is broken up with a platinum rod and ignited at a red heat for several minutes. when it is removed and placed in a beaker for solution. Water is added, together with a few drops of hydrochloric or nitric acid, and the solution is brought to gentle boiling for about five minutes. It is then filtered into the flask containing the soluble phosphorus (or into another flask, in case it is to be determined separately*) neutralized with ammonia and precipitated as ammonium phospho-molybdate. The latter precipitate is titrated according to Handy's modification of the sodium hydroxide method.

[A table of analyses of some eighteen different ores was shown, in which the proposed method was checked up by the standard method.]

The conversion of the insoluble phosphorus into the soluble form, by simple ignition, is a matter of some theoretical interest. Possibly the method proposed by Berzelius for the decomposition of phosphates by means of silica may involve a reaction somewhat similar to it.

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*It has been found that it is better to determine separately the soluble and insoluble phosphorus. Otherwise a too dilute solution is obtained for the precipitation.

A CRITICAL REVIEW OF THE METHODS OF DETERMINING MINERALS.

By Dr. Joseph W. Richards,

Of the Department of Metallurgy and Mineralogy of the Lehigh University, President of the Section.

The determining of a mineral consists in finding out its species, and in doing this so conclusively as toprove that it is the species named to the exclusion of all other similar related minerals.

The question must be met at the outset: "What constitutes a mineral species?" I will answer by quoting our one-time professor of chemistry at the Institute—Dr. Persifor Frazer—whose word in geology and mineralogy carries with it the weight of an authority. Says Dr. Frazer: "Every true mineral is a definite chemical compound or element, homogeneous throughout its parts, and capable of expression in a formula. Its molecule is a distinctive whole—the unit of its mass—and incapable of division as long as the mineral retains its characteristic properties."

It is one of the easiest things in the world to accept the present scientific definition and to forget the laborious steps by which such an apparently simple conclusion was evolved. Dr. Frazer's definition appears to us so nearly self-evident that it is difficult to realize that eighty years ago mineralogists were hotly debating the question as to whether the identity of a mineral consisted in its chemical composition or in the sum total of its physical properties. Thence arose two schools of mineral classification. Werner and his followers adopted the natural-history method of classification on the basis of physical properties alone, and prided themselves on having achieved a classification entirely independent of any aid from chemistry. The other school, of which Berzelius was one of the founders, insisted on the chemical composition as the basis of a proper classification, but were not so exclusive as the other school, and admitted physical distinctions, particularly that of form (*i. e.*, crystallization) into their smaller subdivisions.

It will help, in our further consideration of the subject, to examine more closely these two schemes, particularly the Wernerian.

Cronstedt, about 1750, divided the mineral kingdom into four great divisions, viz.:

I. Earth and stones.
II. Salts.
III. Combustibles.
IV. Ores.

Werner, the first of the illustrious teachers of mineralogy at Freiberg, adopted this division and extended it greatly. He divided the first order into nine genera, as follows:

EARTHS.

1. Zirconian.
2. Siliceous.
3. Aluminous.
4. Magnesian.
5. Calcareous.
6. Barytic.
7. Strontian.

STONES.

8. Diamond.
9. Hallites.

Here, indeed, it would appear that the classification was nothing less than purely chemical, yet it was not. A certain number of external characters which siliceous minerals, for instance, usually exhibit being assumed as generic characters, or as a type of the genus, every mineral possessing those characters, whether it contains any silex or not, is arranged under the siliceous genus. And so with the other of the nine genera. Under these principles, Werner saw no inconsistency in placing sapphire in the siliceous genus and opal in the aluminous. I need not expatiate on the absurdity of this procedure from our modern standpoint, but it is only the stupendous development of chemical investigation in recent years that has lifted mineralogy out of that confusion.

Salts, according to Werner, included only such minerals as have some taste and a considerable degree of solubility in water; and they were divided into carbonates, nitrates, muriates and sulphates.

Combustibles were divided into sulphur, bitumen, graphite and resin.

Ores were divided into as many genera as there were distinct metals found as ores. Thus, all the iron ores constituted one genus. The genera were divided into species, depending on their external characters. This was a true chemical basis to start with, but far inferior to the classification according to the acid ingredient instead of the base.

The key-note of this system is found in the following quotation from Werner himself: "Whenever the external characters and the chemical composition are *at variance,* the species is determined solely by *the external characters.*" According to this method of reasoning, gypsum and selenite were classed as different species because they looked different, although of exactly the same composition, while calamine and smithsonite were classed together as one mineral because they looked alike, although of very different composition.

Coming to the chemical systems of classification, they were far from being above reproach, yet they showed fewer inconsistencies than the other method. Many mistakes were made, it is true, principally owing to the imperfect state of chemical science. The phenomena of di-morphism were yet awaiting the light of Mitscherlich's genius for their explanation, and the reproach was cast on the chemical method that it had to classify together calcite and aragonite as one species, while everybody knew they were different. Many were the hours spent by zealous adherents of the chemical side, in trying to establish by analysis some essential difference between calcite and aragonite and thus to silence their opponents. Mitscherlich's researches on iso-morphism and di-morphism, however, cleared up so many of these difficult points that in 1841 Rammelsberg was able to resuscitate the almost defeated chemical method and to champion it so effectively as to have made it the present accepted basis of mineral classification.

A very striking example of this change of base in mineral classification is shown in the successive standard American works on mineralogy. Shepard's work, issued in 1835, 1844 and 1857, in successive editions, was on the natural-history method. J. D. Dana's first edition, in 1837, followed the same system; the second edition, in 1844, was similar, but described in an appendix Rammelsberg's chemical system; the third edition, in 1850, discarded the natural-history method of classification, and adopted altogether the chemical method. This has been retained in all subsequent editions of this magnificent work, which has become not only the American authority on mineralogy, but, one may almost say, the international authority. The importance of this classification to our discussion merits that it be given at once, in outline, as follows:

DANA'S CLASSIFICATION OF MINERALS.

- I. Native elements.
- II. Sulphides, arsenides, antimonides, selenides and tellurides.
- III. Chlorides, bromides and iodides.
- IV. Fluorides.
- V. Oxygen compounds.
  - (1) Oxides.
  - (2) Ternary oxygen compounds, or oxygen salts.
    - 1. Silicates.
    - 2. Tantalates and columbates, etc.
    - 3. Phosphates, arsenates, vanadates, etc.
    - 4. Borates.
    - 5. Tungstates, molybdates, chromates, etc.
    - 6. Sulphates.
    - 7. Carbonates.
- VI. Hydrocarbons.

It is now proper to inquire into the subject of the identification of a mineral, *i. e.*, its determination.

The question is, how to most quickly, easily and surely identify an unknown specimen. This is not exactly the same sort of question as the one of classifying properly a mineral after it is completely described; they are two aspects of the same problem, but from different points of view; for, as Dr. Sterry Hunt has said: "A natural system of classification is not subordinate to the end of identifying species, but should consider objects in all their alliances and relations." Systems for identifying species are not therefore *necessarily* along the identical lines of mineral classification. However, the natural-history method of classification by outward characters adapts itself very readily to schemes of identification in which the physical properties are given the pre-eminence in determining the mineral. Determinations of hardness, streak, luster, gravity, fusibility, form, etc., are easily made without any special training, and therefore are most useful to beginners in the science of determining minerals. The chemical system of classification, however, at once suggests chemical analysis as the true basis of a determinative method, and lends itself most kindly to that means of identification. Moreover, the methods of chemical analysis, particularly those of blow-pipe analysis, have developed coincidently with the growth of the chemical classification of minerals.

The postulate may be made, that if every mineral species is a definite chemical compound, then the true basis of identifying the mineral should be the chemical analysis. In many cases this may not be the quickest way, but it is bound to be the surest. But, shall we throw away all the aid to be derived from physical tests? By no means. If from the properties at once evident on casual inspection memory suggests a familiar mineral, let chemical analysis at once come in to confirm or deny the determination. *In the great majority of cases, the physical determination is practically valueless without the analytical confirmation;* and there are very few cases in which the chemical confirmation is absolutely unnecessary or useless. On the other hand, whenever a mineral is not at once recognized on inspection, the true basis of search to determine it should be to fix as nearly as possible its composition by chemical analysis, and then to utilize physical tests to distinguish between minerals difficult or impossible to separate by differences in their composition.

Tables based entirely on physical tests have been constructed; mixed tables, based on a combination of both physical and chemical tests have been devised; I have preferred to attack unknown minerals *entirely* from the chemical side, and will later on explain what appear to me the advantages of this method.

It is, of course, superfluous to analyze in detail every one of the numerous schemes of determinative mineralogy which have been constructed; it will suffice to select a few typical examples, and to discuss them on general principles.

Dana gives in an appendix to his text-book on mineralogy one set of tables based primarily on the crystal system, then on luster (metallic and non-metallic), and then with the minerals arranged according to specific gravity. This classification is very useful if the mineral shows clearly its crystallization, and is truly of the system which it appears to be; but every mineralogist knows that minerals are oftener uncrystallized than crystallized, and that in probably one case out of three the system is not what it appears to be. The question of luster may sometimes mislead. The specific gravity may be depended upon in probably three cases out of four. Summing up the probabilities that a mineral could be identified by the use of such a table, they are about one in two if the specimen is crystallized, and not more than one in ten if it is uncrystallized. In scarcely any case would the identification be completely satisfactory without the chemical confirmation.

A set of tables in more extensive use than Dana's, and based also on physical tests alone, is that of Dr. Weisbach, well known in English by Dr. Frazer's translation. The following outline shows the scheme of this classification:

WEISBACH'S TABLES.

I. Minerals with metallic luster.

1. Red. 2. Yellow. 3. White. 4. Gray. 5. Black.

II. ——— of sub-metallic or ordinary luster, and with colored streaks, as follows:

1. Black. 2. Brown. 3. Red. 4 Yellow. 5. Green. 6. Blue.

III. ——— of ordinary luster, with white or gray streak.

1. Very soft. 2. Soft. 3. Semi-hard. 4. Hard. 5. Very hard.

Supplementary table for Class III:

A. Soluble in water.

B. Effervescing in HCl (carbonates).

- C. Not soluble in water or containing CO_2.
  - 1. Containing water—Easily fusible to infusible.
  - 2. Anhydrous—Easily fusible to infusible.

In using these tables, if there is no question as to the luster, or color, or streak, or hardness, that is, if all these properties are normal and observed correctly, the specimen thereupon falls into a class varying in number from five to sixty-three, among which it is to be distinguished by a critical comparison of its other physical properties. In the case of the class of five, this is an easy matter; in the majority of cases, the classes averaging thirty to fifty, this is an arduous or impossible task. We have further to consider that sometimes the luster is doubtfully metallic, frequently the color is not easy to judge, that the streak is often misleading and, most of all, the hardness very seldom to be relied upon. I should say in all fairness, taking all these points into consideration, that a careful observer would not place more than fifty out of one hundred promiscuous specimens in the class to which Weisbach assigns them, and, out of those fifty correctly classed, would not be able to identify over twenty-five with any reasonable degree of certainty without having recourse to the chemical composition for confirmation.

One of the best examples of tables based on mixed physical and chemical tests is that of Von Kobell, which is the basis of the classification so well-known and largely used in the United States, viz.: Brush's. They are as follows:

VON KOBELL'S TABLES.

- I. Metallic luster.
  - a. Native malleable metals and mercury.
    - A. Fusible at 1 to 5 or easily volatile, containing:
      - 1. Arsenic. 2. Selenium. 3. Tellurium. 4. Antimony. 5. Sulphur. 6. None of these.
    - B. Fusible above 5, or infusible, not volatile.
      - 1. Containing manganese. 2. Magnetic B. B. 3. All others.

- II. Without metallic luster.
  - A. Easily volatile or combustible.
  - B. Fusible at 1 to 5.
    - (I) Reduces to metallic button, or magnetic B. B.
      - 1. Silver. 2. Lead. 3. Copper $\begin{cases}\text{with As.}\\ \text{no As.}\end{cases}$
      - 4. Cobalt. 5. Magnetic B. B.
      - 6. All others.
    - (II) Not belonging to (I).
      - 1. Alkaline after ignition.
      - 2. Soluble in HCl without residue.
      - 3. Soluble in HCl, with gelatinous residue.
      - 4. Soluble in HCl, with sandy residue.
      - 5. Insoluble in HCl, has Mn.
      - 6. All others.

- I. Metallic luster.
- II. Without metallic luster.
  - A. Easily volatile or combustible.
  - B. Fusible at 1 to 5.
  - C. Fusible above 5, or infusible.
    - 1. With cobalt nitrate show alumina.
    - 2. With cobalt nitrate show zinc.
    - 3. React alkaline after ignition.
    - 4. Soluble in HCl, contain no silica.
    - 5. Soluble in HCl, contain silica.
      - (1) Hydrous.
      - (2) Anhydrous.
    - 6. Not belonging to the foregoing divisions.
      - (1) Hardness under 7.
      - (2) Hardness 7 or over.

It will be seen that the basis of this classification is primarily and secondarily physical, afterwards chemical composition plays an important part. The superiority of this method over the previous ones based solely on physical tests, *lies almost altogether in the extent to which the chemical tests are introduced.* There is still some uncertainty as to luster being correctly determined, and considerable uncertainty is introduced by the factor of fusibility where it lies anywhere near to five; but, granting that these are correctly determined, then the chemical tests are reached and the uncertainties mostly cease. No one worthy of being called a chemist can mistake sulphur for selenium, or silver for lead; the identification of such characteristic elements is practically a certainty. With such chemical tests as solubility in hydrochloric acid, with a gelatinous or sandy residue or no residue at all, there is still considerable room for uncertainty, and the scheme is weak in proportion as they are introduced.

Dr. Fuchs introduced mixed tables based primarily on chemical composition, and to that extent superior to Weisbach's. As a whole, I have found these tables (or subsequent ones based upon them) to be the most satisfactory tables published. To observers skilled in blow-pipe analysis they furnish the most satisfactory means of identification of an unknown specimen. The scheme is as follows:

FUCHS' TABLES.

(By the Blow-pipe.)

I. Heated B. B. on charcoal.
  1. Volatilizes or burns. 2. Arsenic fumes { metallic. / non-metallic.
  3. Selenium fumes. 4. Shows antimony.
  5. Shows tellurium. 6. Reacts alkaline { soluble. / non-soluble.
  7. Residue magnetic.

II. Reduced B. B. with soda, on charcoal.
  1. Reacts for sulphur and gives metallic button.
  2. Reacts for sulphur and gives no metallic button.
  3. No sulphur reaction, but gives metallic button.

III. Shows manganese in the beads { metallic luster. / non-metallic luster.

IV. Shows zinc with cobalt solution.

V. Soluble in HCl, without residue.
  1. Fusible B. B. (a) Hydrous. (b) Anhydrous.
  2. Infusible B. B. (a) Hydrous. (b) Anhydrous.

VI. Soluble in HCl, to a jelly (silica).
(Classified similarly to V).

VII. Soluble in HCl, with separation of silica (no jelly).
1. Hydrous. 2. Anhydrous.

VIII. Insoluble in HCl, but bead test shows silica.
1. Fusible B. B. 2. Infusible B. B.

IX. Belonging to none of the previous divisions.

The weakest point of these tables is in the action of hydrochloric acid, where there is room for some uncertainty, and where tests for the elements, as in the previous divisions, are generally much more satisfactory. Division IV should also be abolished, and placed as a fourth sub-division of II, for by reducing with soda and a little borax on charcoal, zinc is more certainly identified than by the cobalt nitrate test. Cadmium minerals could also have been included under the same subdivision. Taking these tables altogether, I would call them the most satisfactory of the published tables.

I will end this review by describing the methods of determinative mineralogy taught at the Lehigh University, and which my ten years' experience has proven the most certain way of teaching a student to identify minerals.

First of all, the basis is the chemical identification, but with the aid of physical tests brought in at the most profitable stage of the inquiry.

The observer is to first examine the specimen carefully, noting everything that is to be seen or observed by the most simple tests, such as approximate hardness and streak, but not to spend any length of time, more than a minute or two, at such observation. The object of this casual inspection is to determine whether the mineral is similar to any that the observer has seen before; if it is, and therefore suggests one or even several species, the observer is immediately to make a confirmatory test, preferably chemical, and as general as possible, to see if it can possibly be what is suspected. If the test is affirmative, then other confirmatory tests must be applied, with the particular purpose of excluding all related minerals of closely allied composition. If the test is negative, and no other mineral or minerals suggest themselves, then the general method of procedure, based solely on chemical composition, is to be followed.

As an illustration, suppose a mineral appears on casual inspection to be wavellite. The first test is to determine whether it is a phosphate or not. If it is, then alumina, water and finally fluorine can be tested for to complete the identification. If not a phosphate, it may have been observed that the mineral glowed strongly and gave a calcium flame, which would suggest *aragonite*, and a test for carbonic acid would be in order. Or, it might have been observed that it fused easily, thus suggesting a radiated zeolite, and tests for silica and water would be in order. If none of these were observed, then the mineral would have to be attacked along broader lines, but if any of these tests have resulted affirmatively, then the observer has profited by his previous knowledge to obtain a short cut to the identification of the specimen. It is evident that the wider the observer's previous acquaintance with numerous varieties of numerous species, the more he will profit by his experience and be able to put it to use in identifying the specimen.

If the observer has no definite idea, from this casual inspection, of what the mineral may be, or if the ideas given by casual inspection were negatived by the confirmatory tests, then some regular outline of procedure must be followed, and the following outline is offered as having been used very successfully for several years by your lecturer. Leaving aside the first three items, as being intended for identifying a few simple mineral species, clearing the ground, so to speak, the real classification begins at IV. All the species included in I, II and III are included in the later classes.

The outline is as follows:

LECTURER'S METHODS.

I. If metallic and malleable, look for native metals.

II. If very light and black, examine for hydrocarbons.

III. If it has a taste, examine for chlorides, nitrates, sulphates, etc.

IV. If of metallic, adamantine or resinous luster, test in the *open tube for S, As, Sb, Se, Te.* If present, roast thoroughly and test by beads, flame and reduction.

V. If of any other luster, or if no test is obtained in IV, make *bead test for silica.* If present, make flame test, etc.

VI. If silica is absent, test for phosphates and borates. If test is obtained, make bead test, reduction, etc.

VII. If P and B are absent, test for carbonates. If test is obtained, make flame test, beads, reduction, etc.

VIII. If CO_2 is absent, test for sulphuric acid. If test is obtained, make flame test, beads, reduction, etc.

IX. If SO_3 is absent, test with $KHSO_4$ for volatile acids. If test is obtained, make flame test, beads, etc.

X. If volatile acids are absent, make test IV (open tube), if it has not previously been made.

XI. If open tube has already shown nothing, make the bead tests very carefully, to find the weaker acids, such as Cr, V, U, Ti, Mo. If present, make any other tests.

XII. If weaker acids are absent, substance is probably an oxide. Make any blow-pipe tests not already made.

It will be observed that the outline follows generally the broad lines of the classification of mineral species used by Dana, the primary idea being to class the mineral first by finding its acid constituent. This has the disadvantage of bringing most of the oxides and native metals last in the classification, and makes it desirable that the observer be well-informed with those classes by previous acquaintance, as thus much time is frequently saved. If there is any doubt about the luster, the testing begins at IV; if the luster is certainly not of the kinds therein named, it is best to begin at once at V.

In testing for the acid ingredient, those are tested for first which are most likely to be present (other things being equal), and also those tests are made first which are the quickest to make (other things being equal). Thus, silica is tested for before carbonic acid, because the silicates are more numerous; while phosphates are tested for before carbonates, because the test takes less time.

After an acid is found, the direction of the testing is towards the basic ingredient. It should be observed, however, that if the tests at any time give in any way such information about the mineral that the observer suspects what it is, then let him at once leave the general outline, and by direct tests confirm or deny his suspicion. If, for instance, when testing for phosphorus the barium flame is seen, and the observer then looks at the mineral again and suspects *barite,* then he should test at once for sulphuric acid to affirm or negative his suspicion, without going through the form of testing for carbonic acid. If sulphuric acid is absent, then let him take up the scheme again where he left it, and test in regular order for carbonic acid.

By following these directions, the composition of a mineral, or at least one acid and one base present, can quickly be found. The question then arises, how many minerals can contain the ingredients so far found, and in order to facilitate the search for minerals containing certain elements, I have prepared tables of minerals arranged according to the elements they contain. These tables contain under the heading of each element a classification of all the minerals containing that element, arranged primarily according to the acid ingredients, in the order in which they would be found when following the outline of procedure I have indicated. Under each acid, the minerals are further classified according to the other constituents which may be present, arranged in the order in which they are most quickly and surely identified by blow-pipe tests, followed by these minerals containing only the acid and the base, or possibly containing some other ingredients not recognizable by blow-pipe tests. Wherever, as often happens, a list is obtained of several minerals containing exactly the same ingredients, a small table of physical properties placed to the right gives the means of distinguishing them apart. A sample page is as follows:

LECTURER'S TABLES (sample page).

Copper.

Physical Properties,
Compositions, etc.

Sulphates:

With Pb:
† Cl: Caracolite.
† Fe: Beudantite.
* : Caledonite, linarite.

With Zn:
† Al: Aluminite (impure).
* : Serpierite.

With Fe:
† Al: Cyanotrichite.
* : Phillipite, pisanite.

With U:
† Ca: Uranochalcite.
* : Voglianite, johannite (H_2O—5 per cent.).
: Zippeite (H_2O—16 per cent.).

With Na:
With K:
With Ca:
With Cl:
With H_2O:
* * :

It will be observed that, granting that the experimenter has found sulphuric acid and copper, if he does not at once identify the specimen by that information, his next step should be to reduce with soda for lead and zinc; if lead is found, then tests for chlorine or iron are in order, and if neither of these be present, the mineral must be caledonite or linarite, which must be told apart by reference to their physical properties. If the reduction with soda has shown nothing, the bead test for iron and uranium is in order. If these are absent, the flame test for sodium, potassium and calcium is to be made, and if these are absent, the special test for chlorine and then water. If none of these are present, the mineral will be found in the list following the double asterisks, and distinguished in that list by its physical properties. (The names of these latter minerals, and the physical properties, are omitted in this sample page for lack of space.)

It will be objected to this method that with minerals which may contain small amounts of many ingredients their classification will be very difficult. This is admitted, but by classifying these minerals under each heading that they can possibly come, as well as under that heading where they must invariably come, the careful observer cannot fail to identify them, no matter what known variety of composition they may show.

The essential idea of this method of working is to use the physical properties as suggestive or confirmatory—*suggestive* on casual inspection of what the mineral may be, such suggestion to be confirmed by chemical tests; *confirmatory* after a determination by chemical tests. Conversely, the chemical properties or composition are used as the true *determinative* factors, to which the physical tests are subsidiary or confirmatory. Several years' practical use in the mineralogy laboratory has demonstrated, as far as my experience goes, the superiority of this method of determination, both in reliability and, taking the average, in quickness.

[At the close of the lecture there was shown a portable specific gravity hydrometer, made by Wood & Comer, of Philadelphia, with especial reference to the use of the mineralogist, and which gives rapidly and accurately the specific gravity of pieces weighing not over 1 gram. Its use in the laboratory work at Lehigh University has demonstrated this claim, and shown that it meets the present need for a cheap, portable and accurate instrument for determining specific gravities.]

LEHIGH UNIVERSITY, BETHLEHEM, PA., JUNE 15. 1897.

IN MEMORIAM.

JOHN HALDEMAN COOPER.

John Haldeman Cooper was born at Columbia, Lancaster County, Pa., on the 24th of February, 1828, and died at his home in West Philadelphia, on the 9th of May, 1897.

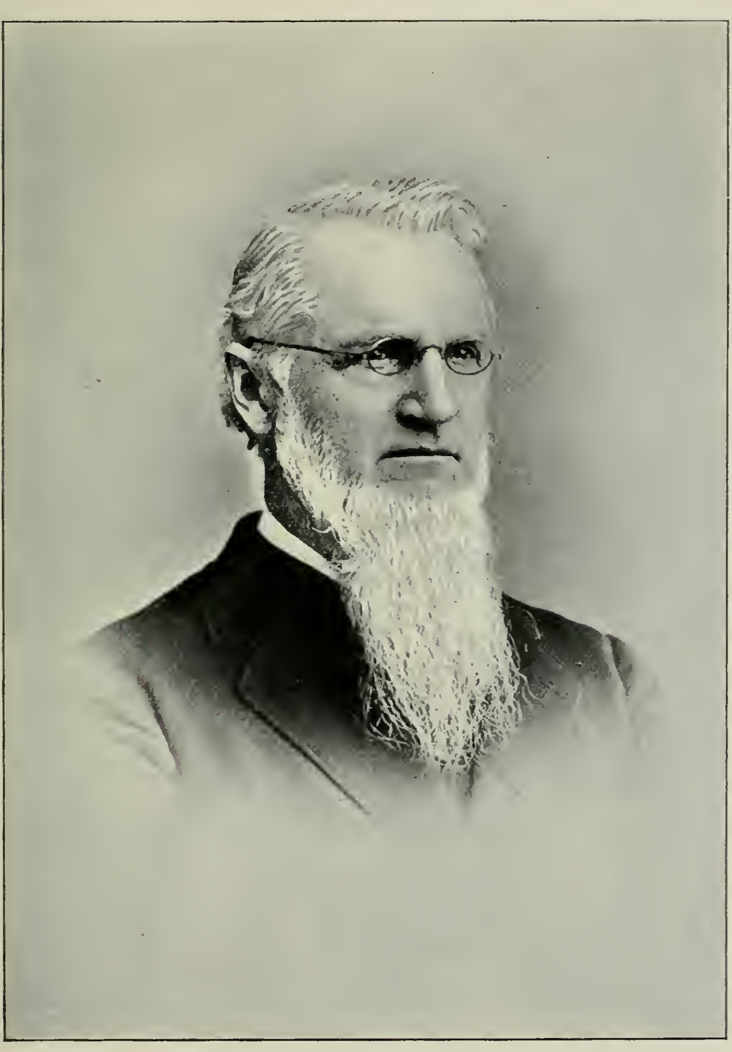
His parents were members of the Society of Friends, and Mr. Cooper remained a member of this body throughout his life. His education and early experiences were obtained under the humble conditions usual in the rural villages of the time.

Those who knew him in his youth recall the mechanical instincts and inventive talents of the boy, and his ardent desire for knowledge, as well as a trait of sturdy integrity, in all of which the boy was father to the man. After a short sojourn in Baltimore, he came to Philadelphia in 1852, and after several years of struggling under adverse circumstances, he established a firm reputation as a reliable and conscientious mechanical engineer.

Shortly after the outbreak of the civil war, he was engaged by I. P. Morris & Co. During his service with them, he had charge of the installation of machinery in the United States monitors *Lehigh* and *Sangamon,* also the *Monadnock* and *Agamenticus.* His work at that period is remembered by his associates for the care and attention given by him to every detail of the work, which was completed without an error. He devised a system of symbols which facilitated correspondence, and aided the workmen in the selection of parts, and subsequently became standard to some extent at the works.

Towards the close of the war, Mr. Cooper was engaged by Jacob Naylor, as superintending engineer of the "People's Works," and during the subsequent fifteen years the results of his efforts were indelibly impressed on the products of that establishment. Amongst other noteworthy work, he produced the best, if not the first, examples in Philadelphia of stationary compound engines, some of which are giving satis-

Jour. Frank. Inst., Vol. CXLIV, August, 1897.



JOHN HALDEMAN COOPER.
(1828–1897.)

factory service to-day. In 1881, Mr. Cooper went to California, on account of his health, which had become impaired, remaining there for three years. In 1884, the Southwark Foundry and Machine Company, of this city, engaged him as superintending engineer. His first work there was the centrifugal pumping plant for the United States Navy Yard at Mare Island. This machinery was of unprecedented magnitude of its class in this country, and involved considerable study and research. The result of Mr. Cooper's labors was a pumping system, which largely exceeded the estimates for capacity, and which has served as a model for similar machinery since procured by the Government. For the past six years Mr. Cooper has been engaged as a consulting engineer and mechanical expert, latterly with the firm of H. R. Worthington, in connection with their cooling tower condenser.

Mr. Cooper became a member of the Franklin Institute in 1856, and served on the Board of Managers from 1870 to 1873, inclusive. He was elected a member of the Committee on Science and the Arts in 1890, and served until his death. His work on this committee was conspicuously conscientious and thorough. His reports on the R. I. compound locomotive and on the Pelton water-wheel were exhaustive historical researches of great merit; and both were published in the *Journal* and largely quoted at home and abroad. His contributions to the *Journal* were numerous, extending at intervals through the series, from volumes 87 to 140, and covered a variety of topics. One of the series, devoted to the subject of belting was subsequently published as a treatise, which passed through several editions, and formed an exhaustive citation of references and opinions on the subject.

Mr. Cooper was a genial, undemonstrative man, who made warm friends, who always held him in sincere regard. He was an indefatigable student and collector of facts, both ancient and modern, relating to his profession. His fund of information and experience was always at the service of others. His liberality in this respect was exceptional, and is remembered with gratitude by many of his friends.

In 1854, Mr. Cooper married Elizabeth Yerkes, who survives her husband and their two children, who died several years ago.

James Christie,
H. R. Heyl,
Washington Jones.

NOTES AND COMMENTS.*

EUROPEAN ELECTRIC RAILWAYS.

L'Industrie Electrique has just published a complete list with details of the electric railways now operating on the continent of Europe and in Great Britain. From these data it appears that Germany is far ahead of any other European country, in both the number of electric railways and length of mileage. Germany also has four roads using storage batteries, and France five such roads. Switzerland also makes a very good comparative showing, viz.:

	Total Length of Lines in Kms.	*Total Power in K. W.*	*Number of Motor Cars.*	*Lines with Aër. Cond.*	*Lines with Undergr. Cond.*	*Lines with Centr. Rail.*	*Lines with Accum.*	*Total No. of Lines.*
Germany	642·69	18,963	1,631	45	2	.	4	51
England	109·42	4,670	168	10	1	6	1	18
Austria-Hungary	83·89	2,589	194	7	2	.	1	10
Belgium	34·90	1,220	73	4	1	.	.	5
Bosnia	5·60	75	6	1	.	.	.	1
Spain	47·00	600	40	3	.	.	.	3
France	279·36	8,756	432	19	1	1	5	26
Holland	3·20	320	14	.	.	.	1	1
Ireland	18·00	486	32	1	.	1	.	2
Italy	115·67	5,970	289	9	.	.	.	9
Sweden-Norway	7·50	225	15	1	.	.	.	1
Portugal	2·80	110	3	1	.	.	.	1
Roumania	5·50	140	15	1	.	.	.	1
Russia	14·75	870	48	2	1	.	.	3
Servia	10·00	200	11	1	.	.	.	1
Switzerland	78·75	2,622	129	17	.	.	.	17
Totals	1,459·03	47,596	3,100	122	8	8	12	150

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* From the Secretary's monthly reports.

BOOK NOTICES.

Entwicklung, Bau u. Betrieb der Elektrischen Öfen, zur Gewinnung von Metallen, Carbiden u. anderen metallurgisch wichtigen Produkten. Von Dr W. Borchers, Lehrer a. d. Königl. Maschinenbau- u. Hütten-schule in Duisburg. Halle a. S. Verlag von Wilhelm Knapp. 1897.

The electric furnace has given the metallurgist a means whereby many problems hitherto impossible of solution may be successfully attacked. It has revealed many entirely new and unsuspected facts in connection with the chemical behavior of substances at extremely high temperatures. It has given to the arts practically an entirely new class of compounds, the metallic carbides, possessed of extremely valuable properties; and when we shall have attained to a more thorough knowledge of the conditions under which the most efficient results may be realized, it will doubtless bring about a revolutionary change in many branches of the metallurgical arts.

In the present volume the author illustrates and describes the various forms of such furnaces that possess distinctive features of originality, and the investigator seeking for information on the subject will find it an extremely useful compendium for his purpose.
W.

Theorie u. Praxis der Analytischen Elektrolyse der Metalle. Von Dr. Phil. Bernhard Neumann, Asst. für Hüttenkunde an der königl. techn. Hochschule zu Aachen. Halle a. S. Verlag von Wilhelm Knapp. 1897.

The application of the electrolytic method for the quantitative analytical determination of metals has been treated of in several publications devoted specially to the subject. The most important of these are the works of Classen and Smith, with both of which analytical chemists generally are familiar.

They have proved most useful in familiarizing chemists with merits of the electrolytic method, which has now come to be regarded not merely as a useful alternative in many analytical separations, but in fact an advantageous substitute for the older standard gravimetric and volumetric methods. The works above named, however, emanating as they do from the pioneer investigators in this field, have naturally enough been restricted, to a large extent, to the methods devised by their authors. The numerous recent contributions to this branch of analytical chemistry, however, make it most desirable that the student and investigator should have at command a more comprehensive work of the class.

The author of the work herewith noticed has endeavored to supplement the work of his predecessors by incorporating therein all the latest and most approved methods of electrolytic analysis, and especially those which have been found to be of technical importance.

He has also endeavored to improve upon the descriptive methods of Classen and Smith by indicating more or less exactly the current strength, voltage, temperature and other conditions essential for attaining the best results.
W.

Theatre Fires and Panics: their causes and prevention. By William Paul Gerhard, C.E. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1896.

The great amount of attention that has, of late years, been given to the subject of this volume, has had a most beneficial effect in doing away entirely with some of the most serious elements of danger in connection with theatre construction and internal arrangement, and in greatly diminishing the risk from others. Nevertheless, despite the most anxious considerations of the fire underwriters' experts, and the wholesome influence of more stringent municipal ordinances, it still remains unquestioned that the circumstances inseparably connected with the operations of the playhouse are such as to render the making of it a thoroughly safe place of resort a matter of extreme difficulty, if it be not really impossible.

Every contribution to the subject of the causes and prevention of theatre fires from expert sources should be welcomed, and where, as in the case of this book, the author makes many sound and sensible suggestions for the lessening of the fire hazard in theatre buildings, and the dangers to life, the work can do much good. W.

The Chronicle Fire Tables for 1897. New York: The Chronicle Company, Ltd. 1897. (Price, $).

We need only say, in connection with these statistical tables, that they are as carefully elaborated and as thorough as those of the previous yearly publications, which have gained for the Chronicle Fire Tables their excellent reputation among fire underwriters.

The tables exhibit some singular facts which would seem to justify the statement in the book that "there is nothing so uncertain as the yearly fire loss." For example, while the number of fires and the number of risks burned increased by thousands (being 61,133 in 1896, as compared with 53,961 in 1895), both the fire and insurance loss fell below the loss of 1895 by millions.

The total fire loss in the United States in 1896 was $118,000,000, or $24,000,000 less than that of 1895, and the insurance loss in 1896 was $31,316,560 as compared with $37,800,440 in 1895. W.

The Watch and Clock Makers' Hand-Book, Dictionary and Guide. By J. F. Britten. Ninth Edition. London: E. & F. N. Spon. New York: Spon & Chamberlain. 1896.

This work is one of the most useful hand-books for the craft in the English language, and the appearance of a ninth edition is good evidence that its utility continues undiminished. An excellent part of the dictionary feature is the addition to the technical terms, of their French and German equivalents, which is a decided advantage to those who use the work for reference. W.

Fuels and Refractory Materials. By A. Humboldt Sexton, F.I.C., F.C.S., etc. London: Blackie & Son, Ltd. 1897.

The object sought by the author in the present work was to prepare a manual dealing concisely, though comprehensively, with the subject of fuel, and which should hold a place between the exhaustive treatises of Dr. Percy, Dr. Mills and Mr. Rowan, and such brief outlines of the subject as are to be found in the manuals of metallurgy, so as to adapt it specially to the needs of students and incidentally also to engineers.

The various chapters deal with combustion, fuels—solid, liquid and gaseous—their preparation; by-products and their recovery; metallurgical furnaces; air supply to furnaces; removal of waste products; smoke and smoke prevention; pyrometry, calorimetry, utilization and testing of fuels; refractory materials, bricks, crucibles, etc.

The arrangement of the subjects considered and the manner of treatment, are most satisfactory, and the value of the work is substantially aided by the number and excellence of the illustrations. W.

The Tutorial Chemistry. Part I. Non-Metals. By G. H. Bailey, D.S.C. (Lond.), Ph.D. (Heidelberg). Edited by William Briggs, M.A., F.C.S., F.R.A.S. London: University Correspondence College Press. Hinds & Noble New York. [n. d.]

This volume forms one of "The University Tutorial Series" prepared for the special use of teacher and student. The subject is, therefore, treated with the object in view of carrying the experimental method of verification along with the statement of the fundamental facts of the science, so that the student may be trained in the scientific method of observation and inferences as he progresses.

The book offers a well-arranged treatise for teaching the elements of chemistry. W.

The Designing and Construction of Storage Reservoirs. By Arthur Jacobs, B.A. Second American Edition, revised and extended by E. Sherman Gould, M. Am. Soc. C. E. New York: D. Van Nostrand Company. 1897. Price, 50 cents.

The present revised American edition of this well-known standard treatise bears evidence of having received the careful attention of the American editor in the form of numerous changes in, and additions to, the editorial notes and remarks which usefully supplement the original text and bring the subject up to date. W.

Encyclopédie scientifique des Aide-Memoire. Librairie Gauthier-Villars et Fils. Paris. 1897.

Two volumes of this work have appeared since our latest notice, viz.:

Electromoteurs et leur applications. Par Georges Dumont, Vice-President de la Société des Ingenieurs Civils de France, etc. (Small 8vo, 2.50 francs unbound; 3 francs bound.)

In this volume the author discusses, first, the various systems of power distribution in vogue in factories and workshops, and passes to the study of electric motors and electric transmission. The author concludes with some judicious considerations of the comparative merits of the electric and mechanical systems of power transmission, and with a review of the principal applications of the electric motor.

Les Transformateurs de Tension en Courants Alternatifs. Par F. Loppé, Ingenieur des Arts et Mfrs. (Small 8vo, 2.50 francs, unbound; 3 francs bound).

This brochure is divided into two parts. In the first, the author deals concisely with the important theoretical question involved in the subject. In the second he treats of the use of transformers, their classification, the calculation of dimensions of an apparatus to fulfil given conditions, and to the description t he principal types of transformers, single and polyphase currents.

W.

The Materials of Construction: A Treatise for Engineers on the Strength of Materials. By J. B. Johnson, C.E , etc. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 1897. Royal 8vo. Pp. 787. Price, $6.

The author has placed at the service of the engineering fraternity a comprehensive treatise on the strength of materials used in construction, in which he has incorporated the most important data derived from recent extensive contributions to scientific testing methods abroad and at home.

The subject is treated under four general heads, viz.: Part I treats of "The Principles of Mechanics Underlying the Laws of the Strength of Materials;" Part II describes the "Manufacture and General Properties of the Materials of Construction;" Part III deals with "Testing Machines and Methods of Testing Materials of Construction; Part IV treats of the "Mechanical Properties of the Materials of Construction, as Revealed by Actual Tests." Several appendices follow.

Of the special features of the work, we have space only to notice the unusual use which the author has made of the stress diagrams and other graphical methods of representing facts and laws, to the corresponding exclusion of data arranged in tabular form. This idea has been consistently carried through the work, and has the obvious merit of impressing on the reader ideas of relationships more profoundly than the mere expression of results in the form of tables. The author also has used throughout the work, in diagrams and text, the English units of weights and measures (pound and inch) on the reasonable plea that "until the metric system has been definitely adopted it is best to use the old units, and that a double system of units is confusing."

An innovation, somewhat radical, though unquestionably meritorious, is the author's adoption of a "new elastic limit," which he proposes to the profession for general adoption.

The work is a highly meritorious contribution to engineering literature, and will, doubtless, receive a warm welcome from the profession.

The publishers have printed and illustrated the book in their usual excellent style.

W.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Mining and Metallurgical Section.

Inaugural Meeting, held April 28, 1897.

MR. JOHN BIRKINBINE in the chair.

THE UNDEVELOPED MINERAL WEALTH OF NEWFOUNDLAND.

BY A. E. OUTERBRIDGE, JR.

The island of Newfoundland, situated at the main entrance to the great Gulf of St. Lawrence, enjoys the distinction of being the oldest land, in a geological sense, in the new world, and the first land upon which was established an English-speaking colony in America.

Mr. James P. Howley, F.G.S., Director of the Governmental Geological Survey of Newfoundland, says:

"The appellation of *Terra-Nova*, or New Land, given to this island by the early navigators, is one of the most ridiculous misnomers conceivable—at least in a geological sense.

"It is, in reality, a very old land, and had an existence, in large part as dry land, when but one small rock in the northeast corner of Great Britain represented that island. The 42,000 square miles, comprising the total area of Newfoundland, are made up of the oldest known geological formations, beginning with the Laurentian and ending with the Carboniferous. Not one of the higher or more recent Mesozoic systems, known to geologists, have any existence here, always excepting the superficial drift, chiefly made up of glacial *débris*, river silt and ordinary clays, derived from disintegration of the surface rocks."

With respect to the date of discovery of Newfoundland, there has been, and still is, some dispute, but the preponderance of evidence is, I think, clearly in favor of the contention that on June 24, 1497, John Cabot landed upon the island and took possession in the name of King Henry VII of England, by whom he was commissioned to explore new lands.

This was only five years after Columbus "sailed the ocean blue," and was more than a century before the landing of the Pilgrim fathers on the shores of New England.

Much interesting and valuable evidence in favor of this claim is presented by Judge D. W. Prowse, Q.C. (Judge of the Central District Court of Newfoundland), in his admirable history of that island, published in 1895 by Macmillan & Co.

Judge Prowse had access, through the favor of Lord Salisbury, to rare unpublished papers and historical records of the Elizabethan era, and Mr. Edmond Gosse, in a prefatory note, states that the work is an original and valuable contribution to early American history, and that the new material was "obtained from records which are, many of them, entirely unpublished."

Judge Prowse gives copies of entries found in the expense accounts of Henry VII, showing gratuities paid to Cabot and his men immediately after their return to England, as rewards for their discovery of the new-found-land.

It is not within the province of this paper to review the history of the expedition of John Cabot, although it is full of interest. A brief reference must suffice to indicate the scope of these investigations to those who may desire to explore the subject more fully.* Through the kindness of a friend, who has been a resident of Newfoundland for many years, I am able to present, in an appendix, an extract from a letter recently received, giving an interesting general description of some of the characteristic features of the island.

In 1881, the late Alexander Murray, F.R.S., then Director of the Geological Survey, published an official geological chart and survey of Newfoundland, made by Mr. Jas. P. Howley, then assistant geologist, who states that as long ago as 1778 a copper mine was opened at Shoal Bay, near Petty Harbor, on the eastern coast. This was probably the first attempt at mining, and copper mining is the most important mineral industry to-day, or rather it is the most fully developed. The official year-book of Newfoundland for 1897 gives tabular statements of imports and exports for the fiscal year ended June 30, 1896, and it therein appears that copper, in the form of ingots, regulus and green ore, was exported during the year to the amount of 64,672 tons.

The principal forms in which copper ores occur are copper-pyrites, glance, tetrahedrite (or gray copper ore), and specimens have been brought in, from outports around Conception Bay, of a very beautiful blue ore of copper, which is probably chrysocolla, or silicate of copper (Cu, 45 per cent.; Si, 34 per cent.).

Lumps of native copper are quite common in a matrix of calc-spar from Blue Mountain Tolt, near Salmon Cove.

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*The charter granted by Henry VII to Giovanni Cabotta (John Cabot) and his three sons—Sebastian, Sancti and Lewes—is dated March 5, 1496, and authorizes Cabot "to sail to all parts, countries and seas of the East, of the West and of the North, under our banner and ensigns, with five ships, and to set up our banner on any new-found-land as our vassals and lieutenants."

Cape Bona Vista, on the southern coast of Newfoundland, is now generally believed to be the point where Cabot landed and established the first English Colony five years after the discovery of the new world by Christopher Columbus.

The copper glance, or vitreous copper, will readily melt in a candle flame, and yields 80 per cent. of copper and 20 per cent. of sulphur.

Tetrahedrite, or "gray copper," as the miners call it, has (approximately) the following composition:

	Per Cent.
Cu	35
S	30
Sb	20
Zn	3
As	7
Fe	5

These are important commercial ores, which have been brought into St. John's from many localities; especially valuable are the copper glance, yellow pyrites and erubescite, from the neighborhood of Placentia Bay and elsewhere. Galena and zinc-blende, or "black jack," and calamine (silicate of zinc) are found in calcareous veins in the lower Huronian formation.

Galena (87 per cent. lead, 13 per cent. sulphur) is found in quartz veins at Tickle Harbor, Trinity Bay and in many other localities; the gangue being calc-spar, brown-spar and occasionally barytes. The best known vein, the "La Manche," is a good example of this form. At Little Placentia small fissures occur, in which a rich argentiferous galena is found associated with zinc-blende and specular iron ore.

Mr. Alexander Murray stated in his report (1881) that specimens from these veins yielded as high as 159 ounces of silver per ton.

"On a few blasts being inserted near the outcrop, one of these veins was found to increase rapidly in thickness and some rich-looking specimens were shown me as the produce. Three such veins were seen to contain ore, and were traced over the surface across a projecting point of the shore about 100 yards. There is great probability, that, owing to the disturbed state of the strata here, generally, these are droppers to a stronger and better defined lode which might reasonably be expected to occur somewhere in the neighborhood."

So far as I am informed, silver mining has never been successfully prosecuted to any extent, although the earliest historical records show that silver was known to exist and this aroused great expectations of future wealth.

About a year ago, two samples of quartz were sent to me from the island for assay for gold and silver. Both specimens closely resembled gold-bearing quartz rock, but analyses gave only microscopic beads or traces of gold and silver, after cupellation with lead.

Iron ores are very plentiful, and a Nova Scotia company has operated for several years quite extensively at Bell-Isle, Conception Bay. The export of iron ore is rapidly growing; the ore is found near the surface, is very economically mined and is loaded on board steamers which run close under the high bluffs and take the ore directly into their holds through chutes. It has been found that the cinder refuse, commonly called "blue billy," from the Newfoundland pyrites, after extracting the sulphur in the manufacture of sulphuric acid, is almost entirely free from sulphur and is a valuable by-product, used in the manufacture of steel. It commands a higher price than similar cinder from any other source.

The Newfoundland year-book for 1897 shows that the export of iron pyrites has increased from 410 tons in 1887 to 36,496 tons in 1896.

Nickel is found in the serpentines, and was worked in a primitive fashion at the Union Mine, Tilt Cove, until the fall in price of nickel rendered the operations unprofitable.

Coal has been found in workable seams at St. George's Bay and on the line of the new governmental railway, which is now almost finished and will be opened during the coming autumn. This railway is a belt line, 564 miles in length, starting from the capital, St. John's, running northward near the coast for more than 100 miles, then veering inland, crossing the island from east to west and running down the coast to the southwestern extremity. This point is only about 80 miles distant from Cape Breton Island across the mouth of the Gulf. A fine fast steamer will convey passengers in a few hours from the railway terminus at Cape Breton to the Newfoundland railway terminus. Prospectors, tourists and others will thus be able to reach all parts of the island within three days' journey from New York, and will avoid the tedious and sometimes dangerous sea voyage from Halifax.

Returning, after this brief digression, to the subject of my address, I am able, through the kindness of Mr. Howley, to give some further statistics from a paper published by him in 1892. Mr. Howley states that a copper mine, known as the "Bett's Cove Mine," was opened in 1875, and actively worked for ten years, during which time 130,682 tons of ore and regulus were exported therefrom, besides 2,450 tons of iron pyrites. The ore occurs in a mass of mixed chloritic slate and diorite. In the course of the excavating some enormous pockets of ore were uncovered.

In 1885, the bluff caved in, owing to having been honeycombed by the excavations, and, although it is thought that the ore was far from being exhausted, operations were discontinued. "The Little Bay Mine was opened in 1878, and before the end of the first season 10,000 tons of ore were raised and shipped to Swansea. Between 1880 and 1885, 61,776 tons were shipped from this mine, and since that date to the end of last year (1891) over 40,000 tons of ore, regulus and ingots of copper are given in the customs returns. Between 1880 and 1882 the Southwest Arm Mines yielded 490 tons; Hall's Bay, 240 tons; Rabbitt's Arm Mine (worked only one year), 1,260 tons, averaging 28 per cent. copper."

The variety of iron ores is very large, and there is little doubt that in future years an extensive export of hematite will be developed, which is found of the richest variety, containing 70 per cent. iron; besides chrome and other ores.

The sample of chrome ore on the table before you, recently received from Newfoundland, was analyzed by the well-known firm of Booth, Garrett & Blair, with the following results:

	Per Cent.
Chromic sesqui-oxide	50
Prot-oxide of iron	40
Silica, etc.	10

This ore is the valuable source of bichromate of potash used so largely in dyeing and paint-making. Chromate of potash or soda is first produced from the ore, and from this base the bichromates, and all of the other pigments, greens, yellows, blues, browns and reds, are obtained.

A remarkable circumstance connected with this industry, which is not generally known, is, that the entire business is in the hands of two families, one in Europe and one in this country. It is said that time and again expensive works have been erected and new chrome products put upon the market, but the old manufacturers have invariably succeeded in killing all opposition by the simple method of reducing prices until the new makers were driven to the wall. As these two firms create the only market for chrome ore, the mine owners are at their mercy. According to Mr. Frederick H. Smith, a well-known geologist of Baltimore, chrome ore containing 60 per cent. of chromium sesquioxide has been sold in that city at $42 a ton.

Two years ago several samples of crude petroleum were sent to me from the west coast of Newfoundland. This was a heavy mineral oil, resembling the Lima fuel oil, and was pronounced by experts an admirable lubricant. I was informed that the samples were obtained by spreading blankets upon the surface of a stream on which the oil floated. The oil was absorbed by the blankets and then squeezed into buckets.

Since that time a well has been bored and the letter, appended hereto, states that a considerable flow has been secured.

There are quite a number of other economic minerals, such as plumbago, manganese, asbestos, rutile, steatite, mica, mineral pigments, etc., of which I cannot now speak in detail.

I can only pause a moment in concluding this address to allude to the great variety of fine building stones found all over the island.

"Granites, syenites, porphyries of every shade of color and consistency, and immense deposits of pure white statuary and mottled marbles range from the mouth of the Humber River northward, towards White Bay, and are again met with in Canada Bay.

"Amongst these are beautifully veined, pale pinkish, bluish, drab, yellowish and some black varieties, all of which take a high polish."*

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*Report of Jas. P. Howley, F.G.S., 1892.

A granite quarry was opened several years ago, which is, I believe, unique in the fact that, owing probably to some great convulsion of nature in past times, the granite has been split into rectangular blocks of various sizes, and of such regular form that schooner loads of selected stones have been procured, ready for the builder's use. In fact, there are buildings in St. John's constructed of these cubical blocks which have been dressed by nature's hand only. If any similar instance is on record, I have failed to find it.

While I have only been able to touch lightly upon the subject of the undeveloped mineral wealth of Newfoundland, I think you will all agree with me that this island may be truly called a natural cabinet of minerals, which will, perhaps, at no very distant day, be opened up for the benefit of mankind.

It is certainly remarkable that this oldest colony of Great Britain in the new world should have remained to this day in so primitive a condition. Until the pathway for the iron rails was blazed across the island the interior was almost a *terra-incognita,* and even now many parts of the interior have never been visited by white men.

History relates that a tribe of aborigines, called "Bethuks," existed on the island when John Cabot landed there in 1497, and two of the savages were taken to England by Sebastian Cabot, where they created much interest. But this tribe has long since disappeared, and there are no native Indians or Esquimaux inhabiting the island.

The coast of the island is exceedingly rugged, and its outline is extraordinarily irregular, being indented with innumerable bays, some of great size. Vast herds of caribou range through the interior, the rivers are alive with salmon, which may frequently be seen leaping rapids, and the smaller streams are filled with speckled trout.

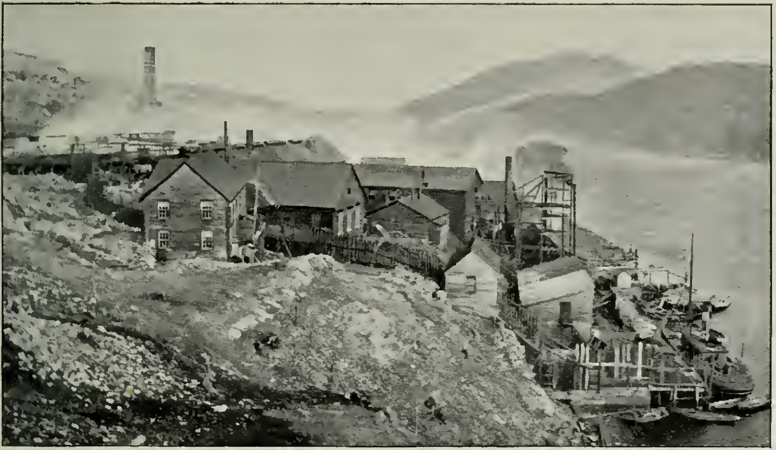
It is said that the simple fishermen dread to venture inland beyond the sound of the ocean, but the opening of the railway will undoubtedly change all of these primitive conditions and lead to an influx of sportsmen, tourists and prospectors.

The Government of Newfoundland realizes that the time has come when the mineral wealth of the country should be

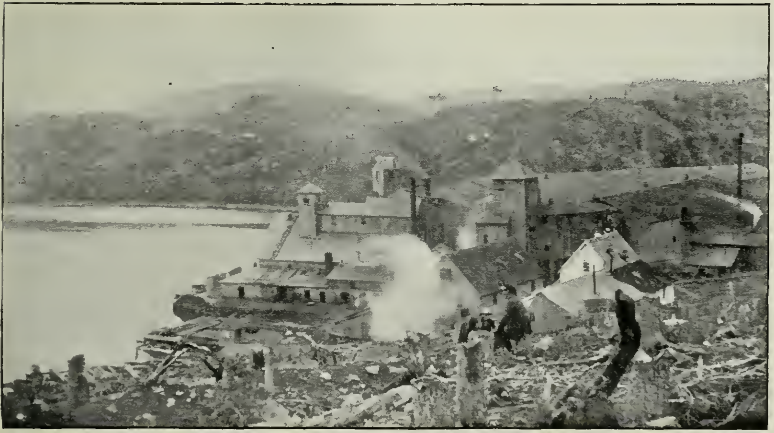
Iron mine at Bell Isle, Conception Bay, showing surface workings.

Iron mine at Bell Isle, Conception Bay, showing ore chutes and loading pier; 1,800 tons of ore were loaded in steamer *Regulus* in 4¾ hours.

(*Outerbridge.*)



Copper mine at Little Bay. Total output about 200,000 tons.



Pyrites mine at Pilley's Isle. Employs a fleet of ships.

developed, and is therefore offering every facility to explorers. License fees to secure a large mining area are fixed at the nominal sum of $20. There is a museum in St. John's, where specimens of all of the minerals which have been discovered are preserved, labeled and catalogued, this is under the charge of the Director of Surveys. Geological reports are furnished from which valuable information regarding the economic minerals may be obtained.

The summer season, though short, is delightful; and an erroneous impression prevails regarding the rigors of winter. Very low temperature is almost unknown, and deep snows are rare. The capital, St. John's, is further south than London, being in the same latitude as Paris. The occasional grounding of large icebergs a short distance from the shore produces astonishing local climatic changes, delaying the ripening of crops and garden fruits, but presenting at sunset magnificent prismatic or iridescent effects.

The coastal steamers, which carry the mails to the outlying ports, as far up as the coast of Labrador, afford an easy means of viewing the bold bluffs and of visiting the mines, all of which are located close to the seaports.

The island is 360 miles in length, and at its broadest part is somewhat wider than its greatest length, but in some places narrow strips of land only separate the great bays indenting the coast on all sides. There are no mountains; but the precipitous bluffs and high hills rising abruptly from the water's edge convey the impression of a mountainous country.

APPENDIX.

[FROM A PRIVATE LETTER.]

The island of Newfoundland has always been so associated with the suggestions of "fog and cod" that probably many people may have imagined its mineral resources to be connected with its general trade and covered by the metal-producing stamp called "C. O. D.," but such is not the case.

The rock-bound shores have scarcely yet been scratched, though thousands of tons of copper, iron pyrites and lead have been shipped, and there is little doubt that a brilliant field is there open to the prospector who will turn his steps a short distance inland, where heretofore, owing to the absence of communication with the coast, scarcely any one has thought it worth while to seek.

Many years ago, a gentleman stood upon the shores of Placentia Bay and observed some fishing smacks approaching the land. Suddenly a squall heeled over one of the boats and revealed a brilliant carmine below the water-line.

On arrival, the skipper was interrogated as to whence the color was obtained. "Over yonder, under the cliff, is a great block of it," he replied, "which, when ground with oil, produces the paint."

Mr. Charles Fox Bennett, the pioneer of mining in Newfoundland—for this was the gentleman—went to the spot indicated, and there found an enormous block of silver ore which had fallen from the cliff. It was too late in the year to prosecute the search further, but the following spring Mr. Bennett arrived with miners, equipped to commence work; but alas! a great landslide had effaced his landmarks, and from that day to this, although many efforts have been made, the supposed rich vein has not been discovered, although indications of its existence have been not infrequent.

Mr. Bennett subsequently opened and worked the Tilt Cove Copper Mine, which has produced abundant supplies of copper and nickel and a small percentage of gold. This mine is still worked by the Cape Copper Company.

Practically no prospecting has been attempted, except on the immediate coast line, but that little has given indications of valuable deposits of many minerals, some of which are about to be vigorously worked by the railway contractor, Mr. Reid, and others. A large surface deposit of iron ore on Bell-Isle was worked last summer by the New Glasgow Steel Company, and other deposits are to be worked during the approaching season, both on the east and west coast.

Until very recently the whole west coast was a forbidden land, owing to the disputed claims of the French; but those difficulties have been partially removed, and enormous known deposits of chrome and other iron ores are likely to be worked in the near future. Workable seams of coal have been discovered, and the new railway will probably be run with native coal during the present year.

Petroleum has also been found on the west coast, and one boring is already yielding a considerable flow.

Asbestos is frequently found on the line of the railroad, but this has not been developed.

The Pilley Island Pyrites Mine employs a fleet of steamers to transport the mineral to the United States. Numerous other deposits are known to exist, but heretofore, the paucity of local capital has prevented their commercial development.

THE UTILIZATION OF ALUMINUM IN THE ARTS.*

By Alfred E. Hunt.
President of the Pittsburgh Reduction Company.

[*Concluded from vol. cxliv, p. 113.*]

Aluminum has been used *in the construction of yachts,* in the sheathing, decks and other construction above the water line, for the purpose of allowing a greater sail area to be carried without danger of the vessel becoming "cranky" or top-heavy.

The victorious yacht *Defender* exhibits a total saving made by the use of aluminum of over 7 tons, the hollow steel boom and gaff of tubular construction also saving another ton of weight.

The tensile strength of the nickel-aluminum plates of *Defender,* which were ¼ inch, 5-16 inch and ⅜ inch thick, 6 inches to 28½ inches wide, and 9 feet to 18 feet 8 inches long, was 40,000 pounds per square inch, with an elastic limit of 30,000 pounds per square inch, and an elongation of 8 to 10 per cent. in 2 inches, the reduction of area at point of fracture being 11 to 15 per cent. The modulus of elasticity was 11,500,000 pounds.

Aluminum is being used in our navy *for lavatory slabs,* air-port shutters and many special castings for various purposes. Aluminum is used in bulkheads particularly for the purpose of preventing danger from shattered pieces of flying wood, due to the action of shells which may pierce the outside plating of a ship in action.

There is a constant and growing demand for nickel-aluminum plates, rivets, bulb-beams, angles and other sections for yachts and steamers of light construction.

Where aluminum is to be alternately exposed to moisture and dryness, corrosion is likely to occur, and this is especially liable to be serious in salt water. In order to protect the metal, it is necessary that it should be coated with an impervious varnish.

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*A lecture delivered before the Franklin Institute, March 26, 1897.

Mr. A. H. Sabin has described in the December (1896) number of the *Transactions* of the American Society of Civil Engineers, an interesting set of experiments on "The Protection of Aluminum Exposed to Sea-Water," by the aid of certain special varnishes.*

An important use for *aluminum* which has just been started is *for parts of furniture.* Book-cases, rat- and vermin-proof, have been neatly made, and are receiving favorable attention from various public libraries.

A serious difficulty is being encountered in the furniture trade because of the difficulty of brazing aluminum sheet into tubing in the way that brazed brass tubing is made. This trouble, however, has already been partially met, and bids fair to be entirely overcome in the near future.

As a conductor of electricity, aluminum has received considerable use in the arts, and is destined to have much larger future applications. Pure aluminum has a conductivity of 63 to 64 per cent. It is practically non-magnetic, and may, therefore, be used for many purposes in electrical work where a magnetic metal would be useless; at the same time, its electrical conductivity is excellent, as the table printed below, giving relative electrical conductivities of various metals, will show.

Aluminum may, therefore, in the future be largely used *in*

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*The aluminum sheets were exposed in sea-water in the Brooklyn Navy Yard for six months' time. Those of the first series, coated with a black enamel, showed absolutely no corrosion when taken out.

Those with a second preparation, called "Durable Metal Coating," made by the Edw. Smith Varnish Company, showed a slight corrosion on the unbaked sides of the sheets. The baked varnish on the sheets showed perfect results.

Another form of their varnish, called "Spar Varnish," with no pigment, one side of the sheets baked, showed on both sides perfect protection of the aluminum.

These plates were suspended in an open oak case or rack, in a horizontal position, about 2 inches apart; the plates being fitted loosely in the rack and suspended at the four corners. The rack was suspended from a float, 6 inches or so below the surface of the water.

The water of the Brooklyn Navy Yard carries considerable sewage and sulphides, occasioning very considerable corrosion with steel or copper plates.

the windings of field-magnets on dynamos where saving of weight is an object, and in general for switches, brushes, brush-holders and apparatus, where its non-tarnishing and non-corrosive qualities should render it specially valuable.

As is the case with other metals of good electrical conductivity, the conducting power of aluminum is greatly decreased as the result of the presence of alloying metals. Pure aluminum has a much higher conductivity relatively to pure copper than is ordinarily given in the books. The lower figures of the earlier determinations were occasioned by the considerable impurities that were present in the aluminum then employed for testing its relative electrical conductivity.

In the early part of the year 1896, tests made of aluminum wire manufactured by the Pittsburgh Reduction Company, by Mr. Charles F. Scott, at the electrical testing laboratory of the Westinghouse Electric Company, and also by Prof. Jos. W. Richards,* at Lehigh University, gave the following results in electrical conductivity.

These samples of aluminum were ·0282 of an inch in diameter, and of the following composition:

		Per Cent. Pure Aluminum.
Sample No. 1		99·50
Sample No. 2		99·00
Sample No. 3		98·00
Sample No. 4	(about)	97·00
Sample No. 5	"	96·00

The impurities in each case were chiefly silicon and some iron.

Sample No. 4, XB, was nickel-aluminum alloy, used in rolling into stiff sections. This alloy contained about 97 per cent. pure aluminum.

Sample No. 5, XCWC, was a stiff alloy, containing copper and zinc, and about 96 per cent. pure aluminum.

Fifty feet of each sample of wire were tested, the wire being wound on wooden spools and immersed in oil. The temperature was varied by placing the spools so immersed into a steam heater, the oil being kept thoroughly stirred. Resistance

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[*] *Jour. Frank. Inst.* **143,** 195.

measurements were made by means of "Wheatstone's bridge."

The resistance of soft, pure copper wire, 1 foot long and 1-1000th of an inch in diameter (unit foot), was taken as 9·720 B. A. units at 0° C.; corresponding to 9·612 legal ohms at 0° C., or 10·20 legal ohms at 15·5° C.

The results of the tests made by Mr. Chas. F. Scott were as follows:

Sample.	Ohms per 1,000 feet ·01 inch diameter at 15° C.	Per cent. Conductivity at 15° C.	Per cent. Variation per deg. between 15° C. and 80° C.
Pure copper wire	101·83	100·00 per cent.	·388
No. 1, 99½ per cent. pure aluminum	161·40	63·09 "	·385
No. 2, 99 " " "	163·80	62·17 "	·385
No. 3, 98 " " "	181·30	56·17 "	·360
No. 4, XB, nickel aluminum alloy	174·10	58·48 "	·361
No. 5, XCWC, copper-zinc aluminum alloy	185·10	55·01 "	·359
Result of Prof. J. W. Richards on the 99½ pure aluminum	—	64·50 "	·300

Relative Electrical Conductivity.

AUTHORITY, ROBERTS-AUSTEN.

Silver (pure)	100·00
Copper "	97·61
* " (refined)	97·50
Gold (pure)	76·61
†Aluminum (pure)	63·00
Magnesium "	39·44
Sodium "	31·98
Zinc "	29·57
Cadmium "	24·38
Calcium "	21·77
*Brass (35 per cent. zinc)	21·50
Potassium (pure)	19·62
Lithium "	18·68
Cobalt "	16·93
*Iron (Swedish)	16·00
Iron (pure)	14·57
Platinum (pure)	14·43
Tin "	14·39
Nickel "	12·89
Bronze (10 per cent. aluminum)	12·60
Palladium aluminum	12·08
*Steel (Siemen's)	12·00

Thallium	(pure)	9·13
Lead	"	8·42
Strontium	"	6·60
Arsenic	"	4·68
Antimony	"	3·59
Mercury	"	1·75
Bismuth	"	1·40
Tellurium	"	·0007

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*Authority, Lazare Weiler. †Authority, Scott & Richards.

M. Charpentier-Page, in the impression of *L'Electrochimie* for April, 1896, publishes electrical conductivity results obtained under his direction, as follows:

ELECTRICAL CONDUCTIVITY.

Pure copper	100
Commercially pure aluminum	62
Aluminum, 97 per cent.; copper, 3 per cent.	49
" 94 " " " 6 " "	44
" 10 " " " 90 " "	13

The wire tested having a diameter of 2 millimeters.

Already the Pittsburgh Reduction Company has furnished several hundred miles of *aluminum wire for movable telephone and telegraphic work.* The facts that the weight of copper wire is 3·3 times greater, and that the tensile strength of the two materials is not very different, have made the use of aluminum wire for field military telephones and telegraph lines especially advantageous.

In castings, *aluminum* alloyed with about 5 per cent. of copper to harden it is just beginning to be used to replace brass castings *in electrical apparatus.* The aluminum alloys used are as easily tooled and take as good threads as brass castings, and the electrical conductivity of the alloys used has been fully up to that of ordinary brass, and better even than that of ordinary copper castings, for the reason that copper, as it is ordinarily treated in making castings, absorbs a great deal of oxygen, which causes it to have markedly lower electrical conductivity than rolled copper, which, although reckoned at 100 per cent., is often lowered to 30 per cent. in copper castings. Nickel-aluminum castings have been made with a conductivity of 50 per cent. in the same scale.

The tensile strength of ordinary copper castings is about 19,000 pounds per square inch, and, in the best results with specially prepared copper castings, has never exceeded 30,000 pounds per square inch, while the nickel-aluminum casting alloys can readily be supplied of a tensile strength per square inch of 25,000 pounds.

The high degree of purity which it is possible to reach in manufacturing aluminum, as well as the purity of the commercial article, compares favorably with that of copper or any of the common metals, as the following table will show:

Table Showing Purity of Aluminum Compared with Other Metals.

	Purest Commercial Product. Per Cent.	Purity of Commercial Metal. Per Cent.
Aluminum	99·90	99·30
Copper	99·95	99·50
Zinc	99·70	99·30
Tin	99·10	98·50
Nickel	99·50	99·00
Lead	99·60	99·00
Iron (in softest steel)	99·85	99·80

Stiff *aluminum sheet* has had quite an extensive use *for card- and book-cases.* The covers of many important record books are now made of aluminum sheet, well rounded at all edges to prevent the subsequent wear of the leather used in connection with the metal sheet upon the books. Several firms are making convenient little pocket tablets to be held in aluminum sheet metal cases, a sample of which is shown. These pocket tablets are especially popular with physicians for their pocket prescription tablets.

The finish of these aluminum sheets has been varied by different methods of working. In scratch-brushing, a brass scratch-brush is run at a high rate of speed. This work can be modified by first taking a leather wheel and very fine Connecticut sand, revolving at a very high rate of speed on a polishing lathe, feeding the sand at the same time between the wheel and the aluminum metal so that the skin and irregular surfaces are removed, then putting the metal on a buffing wheel for scratch-brushing. In this way, a variety of different effects can be produced. A fine brass scratch-brush gives a most beautiful finish to sheet metal or to articles manufactured from the sheet. By this means, a frosted appearance is given to the metal, an effect which in many cases is equal to that given by a high polish.

An appearance similar to the scratch-brush finish can be given by sand-blasting. The effect of first sand-blasting and then scratch-brushing sheets gives a finish with very much less labor than with the scratch-brush alone. Another very pretty frosted effect is secured by first sand-blasting, and then treating as hereinafter described under the head of "Dipping and Frosting."

A very pretty mottled effect is secured on aluminum goods by first polishing them and then holding them against a soft pine wheel run at a high rate of speed on a lathe. By careful manipulation quite regular forms can thus be obtained. This can be varied by first scratch-brushing or sand-blasting, and then holding the articles against a wheel as previously described. Aluminum which has been sand-blasted receives a grain which will allow of printing on the surface of the sheet with the best results, and aluminum sheets thus prepared are coming very largely into use for photo-lithographic purposes. The surface in such cases is first sand-blasted in order that it will take and retain the ink, and produce very clear and sharp outlines when printed from. The faces for cyclometer dials, watch dials and similar articles are generally sand-blasted before they are printed upon, which gives a very fine white background.

Directions for Dipping and Frosting.—Remove the grease and dirt from the plates by dipping in benzine. To whiten the metal and produce a handsome frosted surface, the sheet should be first dipped in a strong solution of caustic soda or potash; then in a solution of undiluted nitric acid; then washed thoroughly in water, and dried in hot sawdust. The sawdust must be of a fine, dry grade, with no resin or pitch that will streak the surface.

For Burnishing.—Use a bloodstone or steel burnisher. For hand-burnishing, use either a mixture of melted vaseline and kerosene oil, or a solution composed of two tablespoonfuls of ground borax dissolved in about a quart of hot water, with the addition of a few drops of ammonia.

Lubricant.—The best lubricant to use on aluminum when being turned in the lathe is either kerosene or water; and in the press, when the metal is being drawn or stamped, vaseline.

Tooling.—The best results in working aluminum can be derived by using a "shearing tool," or, in other words, a tool which is shaped more resembling one used in working wood than for working iron or brass, thus securing a tool with a sharp point, which gives the metal an opportunity to free itself, rather than clog the cutting edge. Tools of all descriptions can be made on this principle, regardless of the purpose for which they are intended, whether to cut a thread or turn to a surface.

Benzine is considered the best lubricant on engravers' tools to obtain a bright cut on aluminum, although naphtha, kerosene, or a mixture of coal oil and vaseline is sometimes used. The benzine is preferred, owing to the fact that it does not destroy the satin finish in the neighborhood of the cut, as the other mixtures will sometimes do, if they are not carefully handled. There is, however, as much skill required in using and making a tool for a bright cut, as in the choice of the lubricant that is used.

Speed Used for Spinning or Buffing.—The best work in spinning aluminum on chucks from 5 to 8 inches in diameter can be performed by running the lathe at 2,600 revolutions per minute. Of course, as the diameter decreases for small articles, this speed can be increased up to 3,200 revolutions per minute, and on chucks larger than 5 or 8 inches in diameter the speed would be decreased somewhat below that given.

In buffing aluminum, the best work is produced by using a buffer from 8 to 10 inches in diameter, at speed of about 3.800 revolutions per minute.

Very fine effects can be produced by first burnishing or polishing the metal and then stamping it in polished dies, showing unpolished figures in relief.

Polishing.—An erroneous idea has become prevalent that aluminum does not require cleaning or polishing. All metals exposed to the influence of the atmosphere and moisture become tarnished and soiled to a greater or less extent, even though, as is the case with aluminum, the actual oxidation of the surface is almost *nil.* A thin film of "matter out of place," called by the housewives by the general name of "dirt," will form upon aluminum as it does upon gold.

Almost any good metal polish will cleanse aluminum. It is necessary, however, that the polish should contain no coarse grit. The ordinary metal polishes used for nickel, silver, etc., usually contain too much coarse material and scratch the surface of aluminum.

It will be found that if aluminum receives one-half the attention that is given to brass, copper, silver or nickel, it will retain its polish with much less labor and remain in a brighter condition than any of these metals.

Aluminum will take and retain a very high polish*—fully equal to that of silver. The truly distinctive and beautiful color of aluminum is brought out in a highly polished plate. Aluminum can be polished on buffing wheels with rouge, the same as brass, and for polishing any considerable quantity of sheet, this method is the most economical.

In the great continental scourges that have played such havoc in far-away parts of the world during the past year—the rinderpest in Africa, the famine and plague in India, as well as in the war between China and Japan—*aluminum* has played an important alleviating part in the form of metallic *covers or cases for compressed foods* hermetically sealed in oil-paper packages. These cases not only form serviceable light covers to protect the food and allow of its rapid distribution in the afflicted districts, but also serve as convenient dishes in which to heat and cook the food at the time of its consumption.

A novel use for *aluminum*, which is likely to become quite a large one, is in *tea-caddies or boxes for the shipment of tea* from the far-away countries of China, India, Japan and Ceylon, where the tea is grown.

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*There are many aluminum polishes on the market. Among those to be recommended are: Acme aluminum polish, "Bon Ami" and ordinary rouge polish.

The common practice now is to ship tea in wooden boxes, lead-lined and sealed in specially prepared paper. Tea-boxes are now being made of thin aluminum sheets about 5-100ths of an inch in thickness, weighing about 7-10ths of a pound to the square foot, the sheets being riveted together in water-tight boxes of the metal, with angles at the inside corners for holding the riveted joints together. The aluminum sheets are given a satin finish on the outside to allow the special printing and marking of the boxes as desired by the tea merchants. These aluminum tea-boxes are lighter and cost but little more than lead-lined wooden boxes that have heretofore been used.

In the use of *aluminum for structural purposes,* the selection of the proper grade that should be used will depend largely upon the specific purpose to which it is desired to apply the metal; but generally speaking, for purposes where aluminum is brought into tension, such as in sheets, or in rolled shapes (as angles, beams, etc.), an ultimate tensile strength of from 32,000 to 40,000 pounds per square inch may be reckoned upon; and a safety factor of 4, gives an allowable working strain of from 8,000 to 10,000 pounds. This, of course, is not for pure metal, but for the stronger alloys.

The ultimate tensile strength of pure metal in plates and shapes may be taken at from 24,000 to 28,000 pounds, and with the same safety factor of 4, it gives an allowable working strain of from 6,000 to 7,000 pounds.

For the alloys of cast aluminum in tension, the ultimate strength may be taken at from 18,000 to 28,000 pounds per square inch; using a safety factor here of 5, as aluminum castings are quite uniform and solid, a working strain is obtained of from 3,600 to 5,600 pounds per square inch.

It is difficult to give a value for the ultimate strength of pure cast aluminum in tension, for the reason that while the ordinary pure aluminum will average about 16,000 pounds per square inch, this can be increased very considerably by cold working, and in some cases to as much as 24,000 pounds per square inch. Assuming the average strength and using a safety factor of 4, gives an allowable working strain of from 3,200 to 4,800 pounds.

In comparison, the alloys of aluminum in rolled plates and structural shapes, such as struts, columns, etc., have an ultimate tensile strength of from 26,000 to 34,000 pounds per square inch, which, using a safety factor of 4, gives an allowable working strain of from 6.500 to 8,500 pounds per square inch.

Pure aluminum sheets and structural shapes in compression have an ultimate tensile strength of from 20,000 to 24,000 pounds per square inch, which, with a safety factor of 4, gives an allowable working strain of from 5,000 to 6,000 pounds per square inch.

Castings of aluminum, in comparison, can be taken at 16,000 pounds per square inch for pure aluminum, and from this to 24,000 pounds per square inch for the alloys. Using again a safety factor of 5, an allowable working strain is given of from 3,200 to 4,600 pounds per square inch. But the pure metal should not be used in castings, except for electrical purposes, as it resembles pure copper in being difficult to cast, and is soft, comparatively weak, and has a large shrinkage. In its stead for most casting purposes, alloys with from 5 to 20 per cent. of copper, nickel or other hardeners should be used.

The alloys of aluminum in rivets and similar shapes in shear have an ultimate shearing strength of from 24,000 to 27,000 pounds; which, using here a safety factor of 6, gives an allowable working strain of from 4,000 to 4,500 pounds per square inch.

The ratios of the ultimate shearing strength to the ultimate tensile strength for double-riveted joints is about 60 per cent.; and for single-riveted joints the ratio is about 70 per cent. The ratio for steel is about 75 per cent.

In bearing, the ultimate value of the alloys of aluminum is from 32,000 to 40,000 pounds per square inch; which, using a safety factor of 4, gives an allowable working strain of from 8,000 to 10,000 pounds.

The attention of those contemplating the use of aluminum for structural purposes is called to the fact that the elastic limit is closer to the ultimate tensile strength than in any other of the commercial metals, and for this reason the safety factor of

4 or 5 means a great deal more than it does in steel or iron, where the same safety factor is used.

Where any great strength in aluminum is desired, the metal should be protected in such a way that its temperature will not be raised very much beyond that of the ordinary atmospheric temperature, for the reason that aluminum melts at a little less than 1,200° F.

The values given above are for temperatures of less than 100° C. (212° F.); for temperatures between 100° and 200° C., the unit strain should be decreased by 50 per cent., and above 200° aluminum should not be designed to be used in strain.

For the *purifying of drinking water,* aluminum is destined to take an important part. Our civilization is just being wakened up, by an increased knowledge of bacteriology, to the necessity of purifying the water supplies of large cities.

For this purpose alum and sulphate of alumina have been used for a considerable time. The active principle of the alum in doing this work has long been known to be the hydrated oxide of aluminum; and it has of late been demonstrated that this freshly precipitated hydrated oxide of aluminum can be prepared from metallic aluminum better than by adding the considerable proportion of sulphate of alumina that has heretofore been used.

Dr. Lugo has suggested the placing of aluminum plates as electrodes in the water to be purified, passing an electric current therethrough, the decomposition of the aluminum largely depending on the amount of impurities in the water. It has been shown that by this process the impurities in the water are coagulated with the hydrated oxide of aluminum around the anodes, and the water thus materially purified.

A process of purifying water has been patented, which consists in subjecting it to the action of a coagulant composed of a comminuted alloy of aluminum and then separating the coagulum from the water through a sand or other suitable filter. The inventor prefers an alloy of aluminum with tin, or some other metal electro-negative to aluminum, with the idea that the aluminum will be decomposed and the water purified more readily than by the use of the pure aluminum for the purpose.

Dr. Lugo, with his plant using the electric current, proposes to force the current (of about 4 volts) through the liquid from anode to cathode, and estimates that with the plant which he had in hand he will decompose about 3 pounds of aluminum per day with 1 horse-power, or 100 pounds of aluminum with about 30 horse-power.

So far, no very large business has been developed with the use of aluminum for the purification of water; but the process is now being actively exploited, and the prospects are that in a little time it will be largely developed.

The rationale is that the gelatinous hydrate of alumina is one of the best purifying agents for water, and that this can be produced in more effective form from aluminum plates immersed in the water than by the addition of a salt to produce the alumina, which, in the case of sulphate of alumina, would leave considerable sulphuric acid in the water.

Aluminum hydroxide, freshly precipitated, has the property of coagulating animal or vegetable matter held in solution or suspension in the water, and of entangling a considerable portion of the minerals held in suspension, and these impurities are carried down with the precipitated hydrate. The addition of chemically prepared hydrate of alumina to the water does not seem to give the same desirable result, the action of the nascent hydrate, when this is generated in the water, seeming to be much more effective than when the already-formed hydrate is added to the water.

Should this process develop as it bids fair to, it would mean a very largely increased demand for aluminum.

For the *minor coinage,* aluminum seems, in some of its hardened alloys, to be peculiarly well adapted. Prof. Jos. W. Richards has preceded me in the Institute* with a very interesting paper, the statements of which, as to the advantages of aluminum for coinage, from my own experience, I can heartily endorse. Already, several countries, including the United

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*See *Jour. Frank. Inst.*

States, India and several South American States, have started to investigate the relative merits of aluminum alloys for the minor coinage. The present 1-cent pieces of the United States (1896) weigh 48 grains troy, and the specific gravity is ·8782. There are 146 of them to the pound.

Their chemical composition is:

	Per Cent.
Copper	95
Tin	3
Zinc	2

The blanks for the 1-cent pieces are 15-20 inch diameter and ·043 inch thick.

The standard 5-cent pieces of the issue of 1896 weigh 77·16 grains troy, and there are 93 of them to the pound.

The chemical composition of same is:

	Per Cent.
Copper	75
Nickel	25

The blanks are 16-20 inch diameter, the thickness being ·062 inch.

The Government has of late been paying for the 1-cent pieces 16½ cents per pound, and for the 5-cent pieces 31·94 cents per pound.

Pure aluminum blanks submitted to the mint for trial have been criticised as too soft, producing a burred edge before the design is brought out upon the dies, with indications of the dies becoming clogged in the working of the aluminum.

This has been occasioned largely by the fact that the same pressure and conditions were used in striking up aluminum coins as in striking the harder metals at present in use for the 1-cent and 5-cent pieces. With the coining presses adjusted for the working of softer metal, in pressure and clearance of dies, etc., it will be quite practicable to stamp up satisfactorily a coin from pure aluminum sheet; but it will undoubtedly be better to use for the purpose a metal which is harder than pure aluminum. Alloys of aluminum with about 10 per cent. of hardening ingredients are now being experimented with, and will, I am confident, be found in the future to be satisfactory for our minor coinage; the alloy being a cheaper material in the cost per hundred blanks for the fabrication than is at present charged for the 1-cent and 5-cent pieces.

Aluminum can readily be alloyed in the manufacture with a small but identifying amount of such metals as titanium, molybdenum, vanadium or similar metals, which would readily distinguish counterfeits by the analysis of the composition, as arrangements could be made with the Government that this particular alloy would not be made up by the aluminum manufacturers except for the purpose of coinage, and it will be found difficult to make these alloys with aluminum in a commercial and economical way, except as they would be made in the reducing pot in the first manufacture of the aluminum.

Rich alloys of these ingredients could be made with from 5 to 10 per cent. of alloying ingredients, the analysis of the alloy made and the material diluted with pure aluminum until it had one-tenth of 1 per cent., or whatever other proportion was decided upon as the distinguishing amount of the ingredients of titanium, molybdenum or the like for the purpose.

A committee of the 54th Congress has been appointed to investigate the relative merits of nickel and aluminum alloys for the minor coinage, and this committee's work will undoubtedly be continued during the session of the 55th Congress.

Aluminum has been extensively used *in brushes and combs.**

Aluminum combs sawed out of hard nickel-aluminum sheet are also convenient and cleanly, and are now becoming quite popular. [Samples of an aluminum brush and comb were shown to illustrate the facts stated.]

Aluminum has been used largely *for military equipments,* especially in European armies, where they are closely watching to cut down from the, at best, heavy weight to be carried by the soldier in heavy marching order equipped for field service.

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*The Florence Manufacturing Company, of Florence, Mass., have been not only pioneers in the use of aluminum for hair brushes, but have also brought out the most satisfactory hair brush yet put upon the American market. They have a novel process by which the bristles of the brush are held in place and made to protrude through the aluminum cases on the front side of the brush. Also, the aluminum back made by them is certainly a very durable, useful, practical and satisfactory innovation in the manufacture of hair brushes.

In canteens, buttons, belt-plates, rings for shelter tents, shoe-pegs and metal parts of the scabbard and sword-handle, aluminum is being largely used. It is probable that it will only be a short time before a much larger use of aluminum for these purposes will be found in this country.

Aluminum has been used *for burial cases or caskets* of various kinds. So far the metal has been only used in the most expensive kinds of caskets, which have sold at retail at not less than $500 each, and this, of course, has made the sale of aluminum caskets a limited one. But when it is taken into consideration that at most there is only $50 to $60 worth of aluminum, at present prices, in the most elaborate aluminum caskets, and that it will be quite possible to make either cast or built-up caskets from plates riveted together, at a cost not to exceed (including the cost of the aluminum) from $75 to $90, it would appear to be only a question of time when aluminum will be very largely used for this service. The metal can be made up into very ornamental shapes for caskets, and its durability will be very considerable. From hygienic considerations, these caskets will surely receive favor among undertakers in the future. It is true that many of the forms of embalming fluids used in preserving bodies contain chloride of zinc, chloride of arsenic, and often some free chlorhydric acid, which will act upon and corrode aluminum. Still it will be practicable to avoid such corroding action by putting lime or similar salts into the caskets, underneath the casket linings, to entirely absorb and neutralize the corroding liquids referred to, and prevent their action upon the aluminum.

The *soldering of aluminum* has so far proved a difficult task. Most solders, such as ordinary hard solder, composed of silver and tin, or ordinary soft solder, composed of lead and tin, will not stick, owing to the high heat conductivity of aluminum. The heat is very rapidly drawn away from any of the molten solders, causing them to "freeze" before flowing sufficiently. Good joints, however, can be made by carefully cleaning the surfaces to be joined, and with very hot soldering bits, or careful work with the blow-pipe, "tinning" the surfaces with some of the special solder used before attempting to join the metals. Several such solders are successfully used, pure tin, with a little phosphor-tin, being the basis of the majority of such solders.

One of the earliest solders proposed for aluminum was that proposed by your fellow-member, Mr. Joseph Richards, who I understand was awarded a medal by the Franklin Institute for his solder, in which phosphor-tin plays an important part.

Another solder for aluminum, made by Edw. N. Cook, 144 Pine Street, Providence, R. I., is called "Green's Aluminum Solder." It is not used with any flux, simply requiring the aluminum faces to be cleaned and first coated with the solder; then with a clean, hot soldering bit, to "wipe" the solder joint to be made.

Green's solder is composed of:

	Per Cent.
Zinc	50·03
Tin	47·99
Aluminum	1·76
Phosphorus	·22

Many fluxes have been proposed in soldering aluminum. Common stearine, as used in wax candles, has been found as efficient as any. Soldering bits of nickel are best to be used, and specially good work has been done with those kept hot by a gasoline torch or electric appliance. Special care should be taken to clean the surfaces to be soldered, which can be successfully accomplished by the mechanical means of scratch-brushing, scraping or filing the surfaces, thus exposing fresh metal free from the thin film of oxide of aluminum and the oxide of silicon (silica), which forms a resistant and protecting coating over the surface of the metal, preventing either the soldering or plating of aluminum.

Another way to clean the surface of aluminum either for soldering or plating is to dip the sheets into nitric acid diluted with three times its bulk of hot water, and which has had added to it just enough hydrofluoric acid to make the solution act on the surface of the metal, this action being denoted by the evolution of gas bubbles. The solution can be kept in either a wooden or lead-lined tank, and the amount of hydrofluoric acid added need be only small, say, less than 5, or at most, 10 per cent. of the volume of the solution. The hydrofluoric acid required is the cheap fluid of commerce sold in lead jugs and costing about 5 cents per pound. The aluminum, after being cleaned in this dilute nitric acid and hydrofluoric acid solution, is again dipped into hot water for rinsing and dried in hot sawdust; it is then cleaned so that either solder or plating solutions can readily be applied.

The difficulty of making durable soldered joints of aluminum lies in the galvanic action which takes place between the aluminum and the metals composing the solder. The common metals are decidedly electro-negative to aluminum in a voltaic couple, and as the electro-positive element is the one attacked first and most severely and the electromotive force (or force produced by the difference in chemical action between aluminum and any of the common metals with which it comes in contact in a voltaic element) is equal to the sum of the electromotive forces between all the intervening metals, it follows that care should be taken that aluminum exposed to water or other solutions should not come in contact with any other metal which will cause a voltaic couple to be formed.

Aluminum can be protected in places where it is exposed to galvanic action by insulating with rubber or canton flannel soaked in a mixture of white lead and oil, or some other non-conducting substance. It can also be protected by placing between the aluminum and the metal with which it is in contact a more electro-positive metal, such as magnesium, where the metal from which the aluminum is insulated is electro-negative to it, as is the case with most metals.

The following table shows what metals are electro-positive or electro-negative to one another:

POSITION IN ELECTRO-CHEMICAL SERIES.

(IN THE ORDER OF THE MOST POSITIVE FIRST.)

1 Caesium,
2 Rubidium,
3 Potassium,
4 Sodium,
5 Lithium,
6 Barium,
7 Strontium,
8 Calcium,
9 Magnesium,
10 Aluminum,
11 Chromium,
12 Manganese,
13 Zinc,
14 Gallium,
15 Iron,

16 Cobalt,
17 Nickel,
18 Thallium,
19 Indium,
20 Lead,
21 Cadmium,
22 Tin,
23 Bismuth,
24 Copper,
25 Hydrogen,
26 Mercury,
27 Silver,
28 Antimony,
29 Tellurium,
30 Palladium,
31 Gold,
32 Iridium,
33 Rhodium,
34 Platinum,
35 Osmium,
36 Silicon,
37 Carbon,
38 Boron,
39 Nitrogen,
40 Arsenic,
41 Selenium,
42 Phosphorus,
43 Sulphur,
44 Iodine,
45 Bromine,
46 Chlorine,
47 Oxygen,
48 Fluorine.

In the *electro-plating of aluminum*, as in soldering, it is necessary that the surface film of oxide of aluminum and oxide of silicon, which is found to exist on any metal which has been exposed for any length of time to influence of the atmosphere, should first be completely removed. This cleansing operation can be accomplished either by immersing in caustic alkali or alkaline carbonate, or immersing in a dilute solution of nitric acid with enough added hydrofluoric acid to cause evolution of gas on the surface of the aluminum. After the surface has been slightly acted upon, it should be rinsed in running water and dried in hot sawdust, if the metal is to be soldered. The surface of aluminum has also been cleaned for plating by boiling in a strong solution of washing soda, which gives a rough surface, with a good "bite" for the plating. The aluminum is then washed and dipped for a moment in a hot solution of hydrochloric acid, say, 50 per cent. It is then plunged for about one-half second into a vessel of clean water and instantly transferred to a three-tenths of 1 per cent. solution of copper sulphate with a trace of acid. The solution will deposit copper on the aluminum in an adherent layer. Also, some gas is evolved during the process. As soon as a uniform deposit of copper is obtained, which takes place in three or four minutes, the aluminum is washed with water and the plating continued in the usual way with copper, brass, silver, gold or other metal.

Several companies, in the past, have been selling sheet iron purporting to be plated or "galvanized," as they call it, with aluminum or with alloys of aluminum and tin. It is a fact that alloys of aluminum and tin can be coated on sheet iron according to the process outlined as having been carried on by the

Tacony Iron and Metal Company, of this city, for plating the iron columns on your Public Buildings; but in most cases the iron sheets purporting to be plated by aluminum have been found on analyses to contain no aluminum at all.

In the plating of the columns of the Philadelphia Public Buildings by the Tacony Iron and Metal Company, the process consisted of plating the metal with an alloy of 75 per cent. aluminum and 25 per cent. tin. The iron columns were first cleaned and then electro-plated with copper in an alkaline bath, a thickness of something like 1-16th inch of copper being obtained in an acid sulphate bath. The aluminum-tin alloy was deposited at a temperature of 130° F., at a current density of 8 ampères per square foot, from pure aluminum anodes, in a bath having the following composition:

	Parts.
Saturated solution aluminate of soda	75
Stannate of soda	25

The bath also contained some potassium cyanide.

The following is a method for plating on aluminum:

The aluminum is immersed first in a bath of acetate of copper dissolved in vinegar, to which oxide of iron, some sulphur and aluminum chloride have been added (*sic*). This gives a deposit of copper over the surface. After this, the article is brushed with a soft brass wire brush and well rinsed in clear water, and is then placed in the electrolytic bath to be plated in the usual manner. If the work is well done, this plating is so strong that no amount of bending will cause it to chip off or crack.

After being plated with silver or copper, the article may be treated by the sulphide process for "oxidizing," giving the same effect as "oxidized silver."

Aluminum is now sold at a price per pound about equal to that of nickel, and not largely in excess of that of German-silver; volume for volume, it is much cheaper than German-silver; and for replacing German-silver or britannia metal *as a base in silver-plated vessels,* its power of retaining heat and its lightness, together with its much cheaper price, will certainly present such advantages as will cause its extensive use.

In the aluminum trade, the manufacturers have been confronted with the anomalous position that it is necessary for them to sell the metal at prices to compete with brass in sheet, wire, tubes, etc., as cheaply as similar articles are sold in brass. To do this, they have been obliged to put in the plant for the efficient and economical working of aluminum in sheets, bars, wire, tubes, etc., upon a scale sufficiently large to produce the best results, and that before the business was sufficiently developed to warrant the installing of the plant.

The brass manufacturers have the advantage of a large business already established, with many plants working under the most economical conditions as to their facilities for rolling, drawing, etc.

It has been the experience so far that the establishments having these facilities for working in brass are not willing to work aluminum at anything like the same relative prices, but have desired a profit of from 50 to 100 per cent. beyond that with which they were content in brass for similar work in aluminum, so that the manufacturers of aluminum have found themselves in the unsatisfactory position of having to put in their own rolling mills and drawing apparatus of the most approved pattern in order to compete in price for work in similar articles of brass. To be compelled to put in the considerable plants necessary for working aluminum at the same time they were developing the business for increasing the output of the ingot metal has proved considerable of a hardship to the manufacturers of aluminum.

So far as the experience of the Pittsburgh Reduction Company goes, it is about the same for an aluminum plant as for a steel plant—that it takes about one-fourth the area of the plant for the actual manufacture of aluminum ingots, and three-fourths of the occupied territory for plant in working up the metal in foundries, rolling mills and the like.

Aluminum has now reached a point in selling price where it is about equivalent to brass for many purposes. Brass averages from 3·15 to 3·20 times heavier than aluminum; and when the price of brass per pound is multiplied by this factor, it will be seen that aluminum to-day is really a cheaper metal than brass, for many purposes, and that it will in the future be a question of the "survival of the fittest" between the two metals.

It will take years before workmen will gain the experience in handling aluminum as adeptly as brass, occasioned by life-long experience in working brass. It will take years before the stock of dies will have accumulated with the proper clearance for aluminum over that needed for brass; so that even with aluminum eventually coming out the superior metal, manufacturers must reckon upon only a gradual approach of tonnage of aluminum consumed to that of brass.

For many purposes brass is undoubtedly the superior metal. It is essentially a better bearing metal than aluminum. It can be brazed, as aluminum cannot be at the present time—a difficulty which handicaps aluminum from being used in place of brazed brass tubing, etc. Brass can be subjected to a higher temperature under working conditions than can aluminum with its lower melting point; and brass can be soldered more easily than aluminum, and the soldered joints made much more lasting.

Aluminum is a very sonorous metal, and it has been used quite extensively for gongs in the place of brass.

In metal sheets, whitened by scratch-brush or other form of satin finish, *aluminum has replaced brass for clock faces* to a considerable extent.

It is evident that for any use of aluminum in the form of sheets, bars, tubes, wire or castings, its light weight relatively to other metals should be taken into consideration in comparing the relative costs for any given purpose.

The common metals—wrought iron, cast iron, steel, copper, zinc, tin, lead, brass, bronze, German-silver, nickel, antimony and britannia metal are all much heavier; and the relative economy in using them in either the cast or worked shape can only be arrived at by multiplying the price of the heavier metal by the factor of its specific gravity relative to the specific gravity of aluminum.

For convenience in these calculations, the following table is given:

METALS.	Specific Gravity.	Factor of Specific Gravity relative to Aluminum.	Selling price per pound New York Market in May, 1896, in large lots.	Relative selling price per pound New York Market to Aluminum obtained by multiplying price per pound by factor given in column B.	Value per pound that Aluminum is thus relatively cheaper.	Value per pound that Aluminum is relatively dearer.
	A	B	C	D	E	F
No. 1 aluminum, cast	2·56	1·000	$0.35	$0.35	$ —	$ —
No. 1 aluminum, wrought	2·68	1·000	.45	.45	—	—
Commercial copper, cast	8·85	3·457	.1025	.354	.004	—
Commercial copper, wrought	8 93	3·332	.14	.466	.016	—
Tin, cast	7·29	2·848	.1345	.383	.033	—
Tin, wrought	7 36	2·746	.20	.549	.199	—
Bronze, 16 tin, 84 Cu, cast	8·832	3·451	.12	.414	.064	—
Bronze, 16 tin, 84 Cu, wrought	8·90	3·321	·18	.597	.147	—
Britannia metal, cast	7·261	2·836	.125	.354	.004	—
Britannia metal, wrought	7·301	2·724	.200	.545	.095	—
Twenty per cent. German-silver, cast	8·60	3·360	.16	.538	.188	—
Twenty per cent. German-silver, wrought	8·70	3·246	.2925	.949	.459	—
Nickel, cast	8 287	3·237	.35	1.133	.783	—
Nickel, wrought	8·67	3·235	.45	1.456	1.006	—
Brass, 33 Zn, 67 Cu, cast	8·32	3·250	.095	.309	—	.041
Brass, 33 Zn, 67 Cu, wrought	8·549	3·190	.12	.383	—	.067
Antimony, cast	6·71	2·621	·08	.210	—	.140
Lead, cast	11·36	4·438	.0308	.1367	—	.2133
Lead, wrought	11·38	4·247	.045	.1911	—	.2589
Zinc, cast	6·861	2·680	.0410	.1099	—	2401
Zinc, wrought	7·191	2·683	.06	.1620	—	.2880
Steel, cast	7·82	3 055	.025	.0764	—	2736
Steel, wrought	7·858	2·932	.016	.0469	—	.4031
Iron, cast	7·218	2·820	.006	.0169	—	.3331
Iron, wrought	7·698	2·872	.015	.0421	—	.4079

The first uses to which aluminum was applied were naturally those which would stand the high cost of the metal at its selling rate of $10 to $15 per pound.

The first considerable use of the metal was for tubes of opera-glasses and other optical instruments. Then as the metal became lower in price, it was used in thin sheet and metallic foil in a similar way to gold and silver. It was also used in powder made from the foil. Thereafter came the use of the metal in the manufacture of a large line of fancy goods, where the cost of the metal used was a small proportion of the total cost, including the workmanship involved. These, for a considerable length of time, were the staple uses for aluminum; but the tonnage—or rather, to be more accurate, the "poundage"—of metal which could be used for these articles was of necessity very limited; and before the aluminum could be used like other metals, the price had to be materially reduced. This was done in the years 1891 and 1892—at first due to accidents of patent litigation, and before the companies then manufacturing aluminum by the present process had so far perfected the process and increased the capacity of their works really to warrant the decreased selling price by their cost of manufacture; but since the year 1892, with the greatly improved and extended facilities for production, introduced by the large manufacturers of aluminum, they have been enabled gradually to reduce the selling price, until to-day the rate is such that aluminum is a cheaper metal, section for section, than copper, and as cheap as brass.

One of the earliest banes of our commercial life in the *aluminum* business was communications, and in some cases interviews, with *flying-machine cranks*, who were very sure that with the aid of the new metal aluminum, which they maintained was three times as strong, as well as three times as light as steel, they should be able to accomplish that in which Darius Green had failed.

Impossible pieces of apparatus, in crude models, and often in sketches in which plan, elevation, section and projection were all sadly jumbled, were sent to the Pittsburgh Reduction Company, together with letters of interminable length, ordinarily in the poorest of penmanship and with words spelled askew. These people ordinarily imagined that because the Pittsburgh Reduction Company advertised to sell aluminum, they should therefore manufacture any articles of the metal which might happen to be devised. Fortunately, the number of these inventors seems to be growing less; and it has been the good fortune of the Pittsburgh Reduction Company to have sold, to men of real scientific attainments, aluminum materials—mostly in the shape of hardened alloys—which have been successfully used in aëroplanes, balloons and other forms of flying-machines; and in whatever form the flying-machine of the future is to find its most successful developments, it is safe to predict that the use of aluminum as a structural material will have an important part.

Aluminum has been suggested for many purposes for which it is not adapted. Prominent among these may be mentioned cases where much soldering or brazing of the metal has to be done. Because of the difficulties I have already outlined, in soldering and brazing, the use of aluminum has, in most such cases, failed.

Another source of failure of the metal has been in attempts to apply it where gas or liquids are confined under heavy pressure in aluminum apparatus.

Aluminum has so far proved so open and porous in its texture as to be incapable of withstanding, in the form of castings, more than 100 pounds per square inch, without leaking. Undoubtedly, in the future, better work will be accomplished and aluminum castings will be made which will withstand higher pressures without suffering liquids or gases to percolate through the pores of the metal; but, so far as the writer is aware, this has not been found to be the case in commercial work of pure aluminum and alloy castings of the present day.

Another source of failure of aluminum in the arts has been the attempt to use it under high temperatures. The melting point of aluminum, according to the latest experiments, is 1,200° F. The "critical point," if I may be allowed to use this term in this connection, that is, the place where the metal begins markedly to lose tensile strength, is lower comparatively for aluminum than for metals of higher melting points. While it is true that copper, steel and similar metals all markedly lose in strength when heated to over 500° F., with aluminum the temperature at which the metal begins to lose materially in tensile strength is between 300° and 400°; and the writer would not recommend the use of aluminum where the temperature is in excess of 300° F. This will preclude the attempts which have been made to use aluminum for steam boilers and steam apparatus of similar character where the pressure is high. It has been found that a small percentage of iron materially raises the melting point.

Aluminum does not volatilize at any temperature ordinarily produced by the combustion of carbon, even though the high temperature be kept up for a considerable number of hours. It, however, is not good practice in making castings of aluminum to heat it much above its melting point, or to allow it to remain melted for any great length of time, on account of its capacity for absorbing gases.

The latent heat of fusion of aluminum, according to Prof. Jos. W. Richards, is 29·50 calories (kilogrammes), or, expressed in heat units (pounds), 53·00.

The mean specific heat of aluminum from zero to the melting point is very high, being 0·2185, water being taken as 1. This means that the quantity of heat which would raise the temperature of any given quantity of aluminum through 1° would raise the temperature of the same quantity of water through ·2185 of 1° only. Aluminum follows the general law of specific heats, *i. e.*, that they are inversely as their atomic weights.

The linear expansion of aluminum is relatively very high, being exceeded only by zinc and lead of the common metals. The following table shows the expansion per degree per unit of length of the various metals in relative order:

COEFFICIENTS OF LINEAR EXPANSION.

AUTHORITY, ROBERTS-AUSTEN.

	Cent.	Fahr.
Potassium	·0000841	·0000476
Sodium	·0000710	·0000395
Indium	·0000417	·0000231
Cadmium	·0000306	·0000170
Thallium	·0000302	·0000168
Lead	·0000292	·0000162
Zinc	·0000291	·0000161

Magnesium	·0000269	·0000150
Aluminum	·0000231	·0000130
Tin	·0000223	·0000124
Silver	·0000192	·0000107
Tellurium	·0000167	·0000093
Copper	·0000167	·0000093
Bismuth	·0000162	·0000090
Gold	·0000144	·0000080
Nickel	·0000127	·0000071
Cobalt	·0000123	·0000070
Iron	·0000121	·0000069
Palladium	·0000117	·0000065
Antimony	·0000105	·0000058
Ruthenium	·0000096	·0000053
Platinum	·0000089	·0000050
Rhodium	·0000085	·0000046
Iridium	·0000070	·0000039
Osmium	·0000065	·0000036
Arsenic	·0000055	·0000031

The thermal conductivity of aluminum is very high, and is exceeded only by one of the baser common metals, *i. e.*, copper, all the others being less, iron having but one-third as much.

The following table gives the metals in their order:

RELATIVE THERMAL CONDUCTIVITY.

AUTHORITY, ROBERTS-AUSTEN.

Silver	100·00
Copper	73·60
Gold	53·20
Sodium	36·50
Magnesium	34·30
*Aluminum	31·33
Zinc	28·10
Cadmium	20·06
Tin	15·20
Iron	11·90
Steel	11·60
Lead	8·50
Platinum	8·40
Antimony	4·03
Bismuth	1·80
Mercury	1·30

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*Wiedermann & Franz give for Thermal Conductivity of
Aluminum annealed .... 38·87
" unannealed .... 37·96

The importance of the aluminum industry is emphasized by its now supporting a number of papers devoted distinctly and exclusively to its interests.*

Taking the whole field into consideration, as to the uses thus far made and proposed for the metal aluminum, it is my judgment that while there was consumed in the United States only between 600 and 700 tons of aluminum in the year 1896, and while the amount consumed in the present year, 1897, will probably not exceed double that amount of metal, it will probably reach, by the year 1898, at least 2,000 tons per annum, if general business conditions are good.

How greatly this consumption will be exceeded in the year 1900 can hardly be conjectured. As a random guess (which, however, is based upon a considerable study of the situation), I will estimate the consumption of aluminum in the United States for the year 1900 at 10,000 tons.

This estimate, I am aware, is sadly below the roseate estimates of the early writers upon aluminum. Especially is it under the prospects held forth in the many forms of prospectus of would-be inventors of aluminum processes. Still, as a practical manufacturer of aluminum upon a commercial scale, and in touch to a considerable extent with the present development of the uses of aluminum in the arts, from all information which I have in the matter, I will consider the circumstance a most fortunate one if the estimate of 10,000 tons of aluminum as the consumption of the United States in the year 1900 should be verified.

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*In this country the *Aluminum World* is published at 14 Lafayette Place, New York City. In France, *L'Aluminium,* 26 Rue Brunnel, Paris, and *L'Electrochimie,* Review of the Science and of the Industry of Aluminium, 37 Rue de Berne, Paris. In Great Britain, *Aluminum and Electrolysis,* 1 Crosskey Sq., E. C. Little, Britain, London.

PISTON PACKING RINGS OF MODERN STEAM ENGINES.

By Otto C. Reymann,

With Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

[*Concluded from vol. cxliv, p. 126.*]

The bending moment M was found to be variable, its value depending upon angle α. As the Ramsbottom ring is of a uniform cross-section, I is constant and also r and E. Consequently the radius of curvature ρ must be variable in order to fulfil equation (7). Introducing

$$I = \frac{h\,t^3}{12}$$

and from equation (4) $M = p\,r^2\,h\,(1 - \cos\alpha)$ equation (7) is written:

$$\frac{1}{\rho} = \frac{1}{r} - \frac{12\,p\,r^2\,(1 - \cos\alpha)}{E\,t^3} \qquad \text{(B)}$$

and for

TABLE 2.

α	$\frac{1}{\rho} =$	$\rho =$	$p =$
0°	$\frac{1}{r}$	$\rho = r$	$= 0$
90°	$\frac{1}{r} - \frac{12\,p\,r^2}{E\,t^3}$	$\rho_1 = \frac{E\,r\,t^3}{E\,t^3 - 12\,p\,r^3}$	$\frac{E}{12}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_1}\right)$
180°	$\frac{1}{r} - \frac{24\,p\,r^2}{E \cdot t^3}$	$\rho_{max} = \frac{E\,r\,t^3}{E\,t^3 - 24\,p\,r^3}$	$\frac{E}{24}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_{max}}\right)$
270°	$\frac{1}{r} - \frac{12\,p\,r^2}{E\,t^3}$	$\rho_1 = \frac{E\,r\,t^3}{E\,t^3 - 12\,p\,r^3}$	$\frac{E}{12}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_1}\right)$
360°	$\frac{1}{r}$	$\rho = r$	0

The values for ρ compiled in this table are calculated with the ring pressure p taken constant around the whole ring; the last column may be used in finding the pressure p exerted by the packing ring, if the radius of curvature ρ is known.

Example No. 1.—Ramsbottom packing rings are frequently used in locomotive engines. Here usually the rings have to carry a part of the piston weight, and, consequently, are more rapidly worn on their lower half than on their upper half. By having them fit loosely in their grooves, the vibration of the engine causes the rings to slowly move around, thus bringing each element of the ring surface by and by to the points of greatest pressure. This equalizes the wear greatly, and a uniform distribution of the pressure almost over the whole circumference of the packing ring is the result. Rings of uniform cross section are, therefore, used on locomotive pistons. Let us suppose we have a cast-iron packing ring of ½ x ¾ inch cross section for an 18½-inch steam cylinder. Then $r = 9\frac{1}{4}$ inches, $h = \frac{1}{2}$ inch, $t = \frac{3}{4}$ inch. If this ring shall exert a $p = 6\frac{1}{2}$ pounds, the greatest stress opposite the cut at point D is according to equation (A),

$$f = 12 . 6\tfrac{1}{2} . \left(\frac{9\frac{1}{4}}{\frac{3}{4}}\right)^2 = 11{,}865 \text{ pounds per square inch.}$$

or about one-fourth of the breaking stress, assuming a material similar to that tested by Mr. Vogt. Then with $E = 13{,}300{,}000$, the radii of curvature necessary to produce a pressure of 6½ pounds per square inch are found by equation B to be at point D.

$$\rho_{\max} = \frac{13{,}300{,}000 . 9\frac{1}{4} . (\frac{3}{4})^3}{13{,}300{,}000 . (\frac{3}{4})^3 - 24 . 6\frac{1}{2} . (9\frac{1}{4})^3} = 9.46''$$

and at C or E:

$$\rho = \frac{13{,}300{,}000 . 9\frac{1}{4} . (\frac{3}{4})^3}{13{,}300{,}000 . (\frac{3}{4})^3 - 12 . 6\frac{1}{2} . (9\frac{1}{4})^3} = 9{\cdot}35''$$

As $\rho_{\max}$ differs only little from ρ, the cylinder from which the rings are cut off may be turned 18·92 inches in diameter, and the proper curvature at point C or E can then easily be obtained by filing off the ends of the ring after it has been cut.

V. *Ring of Variable Thickness.*—Discussing equation (7)

$$E\,I\left(\frac{1}{r} - \frac{1}{\rho}\right)$$

it was said that M was variable and that therefore at least one factor on the other side of the equation must be variable, too, in order to fulfil the equation for any value of α. E and r are always constant, no matter what type of ring is selected. However, ρ and I depend entirely upon the shape of the packing ring. Hence, either or both can be variable at the same time.

If the outside of the ring is made into a circle: $\rho =$ constant and then

$$I = \frac{M}{E\left(\frac{1}{r} - \frac{1}{\rho}\right)}$$

For a rectangular cross-section we have

$$I = \frac{t^3 h}{12}$$

and therefore

$$t = \sqrt[3]{\frac{12\, M}{E.\, h.\, \left(\frac{1}{r} - \frac{1}{\rho}\right)}} \tag{8}$$

Substituting for M its value, we get for a cross-section at C or E (*Fig. 5*):

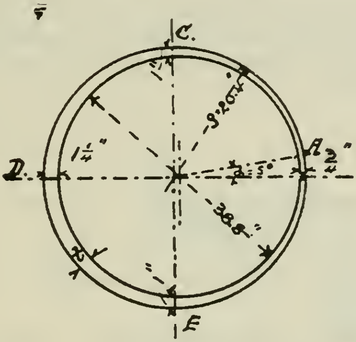


FIG. 5.

$$t_1 = r \sqrt[3]{\frac{12\, p}{E} \quad \frac{1}{1 - \frac{r}{\rho}}} \tag{C}$$

and as maximum thickness at point (D)

$$t_{\max} = 2\, r \sqrt[3]{\frac{3\, p}{E} \quad \frac{1}{1 - \frac{r}{\rho}}} \tag{D}$$

Combining equations (8) and (D) we get the ratio

$$\frac{t}{t_{\max}} = \sqrt[3]{\frac{1 - \cos\, a}{2}} = \sqrt[3]{\sin^2 \frac{a}{2}}$$

After $t_{\max}$ is determined the thickness for any cross-section may be taken from Table (3):

TABLE NO. 3.

α	$t =$	α	$t =$
10° or 350°	·197 $t_{\max}$	120° or 240°	·909 $t_{\max}$
15° " 345°	·257 "	135° " 225°	·948 "
30° ' 330°	·406 "	150° " 210°	·977 "
45° " 315°	·527 "	165° " 195°	·994 "
60° " 300°	·630 "	180°	1·000 "
90° " 270°	·794 "		

Example No. 2.—Let the cylinder bore be 40 inches. A cast-iron packing ring, having a maximum cross section of 1¼ x 1¼ inches, is turned ·02 x 40 larger in diameter than the cylinder bore or its radius of curvature $\rho = 20{\cdot}4$ inches. Assuming $E = 18{,}000{,}000$ pounds, we find the pressure produced by this ring in table No. 2

$$p_{180^\circ} = \frac{18{,}000{,}000}{24}\left(\frac{1\frac{1}{4}}{20}\right)^3 \cdot \left(1 - \frac{20}{20{\cdot}4}\right) = 3{\cdot}65 \text{ pounds per square inch.}$$

Equation (A) then gives as fibre stress at the cross section opposite the cut

$$f_{\max} = 12 \,.\, 3{\cdot}65 \left(\frac{20}{1\frac{1}{4}}\right)^2 = 11{,}213 \text{ pounds per square inch.}$$

The ring thickness t_1 corresponding with $\alpha = 90°$ or $270°$ follows from table No. 3;

$$t_1 = {\cdot}794 \,.\, 1\tfrac{1}{4} = {\cdot}9925 \text{ inch, say } t_1 = 1 \text{ inch,}$$

and the intensity of stress at this cross section

$$f = 6 \,.\, 3{\cdot}65 \,.\, \left(\frac{20}{1}\right) = 8{,}760 \text{ pounds per sqare inch.}$$

According to table No. 3, theoretically a thickness equal to zero would be required for each end of the ring, if only the condition—the pressure exercised by the packing ring shall be uniform—were to be fulfilled. The necessity of maintaining a steam-tight joint, however, fixes the smallest thickness of the ring at ¾ inch. Consequently, p can only be constant for the middle of the circumference and increases towards the two ends at the cut.

If we lay out the ring according to the thickness calculated for each cross section from the above table, we find that a circle of 38·8 inches diameter fits the theoretical curve approximately. The pressure now obtained at point A ($\alpha = 5°$) amounts to (equation B)

$$p = \frac{E}{12}\left(\frac{t}{r}\right)^3\left(\frac{1 - \frac{r}{\rho}}{1 - \cos\alpha}\right) = \frac{18{,}000{,}000}{12}\left(\frac{\frac{3}{4}}{20}\right)^3\left(\frac{1 - \frac{20}{20{\cdot}4}}{1 - \cos 5}\right) = 395{\cdot}5 \text{ lbs.}$$

and gradually decreases as shown by table (4)

TABLE NO. 4.

a	t	p	a	t	p
5°	$\frac{3}{4}''$	395·5 lbs.	45°	$\frac{13}{16}''$	6 8 lbs.
10°	$\frac{3}{4}''$	105·45 "	60°	$\frac{7}{8}''$	5·02 "
20°	$\frac{49}{64}''$	26·37 "	90°	1″	3·75 "
30°	$\frac{25}{32}''$	13·3 "			

Although these values are only approximate, as the formulæ used were derived under the assumption that p is constant for the whole circumference, they give sufficient evidence why this type of packing ring bears so much harder on the extreme points at the cut. If we reduce t_{5° from ¾ to ⅝ inch, that is only ⅛ inch, p_{5° would be 228 pounds, and only little more than one-half of the pressure obtained before. The advantage of tapering the rings toward the cut and the importance of a loose fit for this type can be easily recognized.

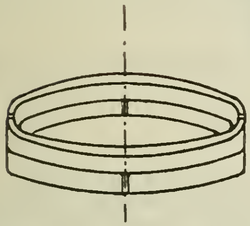


FIG. 6.

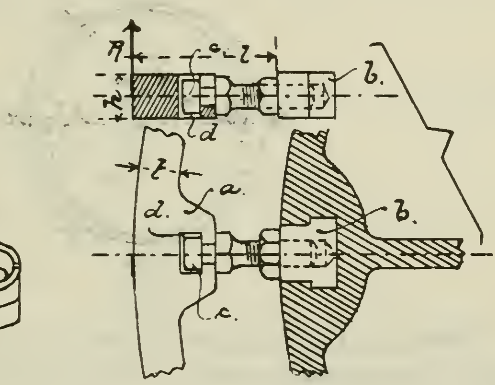


FIG. 7.

VI. *The Crescent Type Packing Ring.*—The examples given in the foregoing chapters show the importance of machining the rings to their correct theoretical shape. In the Crescent type packing ring this is greatly facilitated as its inner surface does not require any machining at all, but is left rough. The length of the circumference is one-half of a full circle, corresponding with $a_{\max} = 180°$. Otherwise this type is very similar to the ring treated in the last chapter. The breadth being uniform, the thickness of the cross-section gradually decreases towards the ends. Since the length of the circumference is only $= r\pi$, two rings must be placed in the same plane, making a total of four rings for one set. As a piston generally carries two sets of packing rings a groove of four times the breadth of one packing ring must be turned in the circumference of the piston block. In order to prevent undue leakage of steam the peculiar shape of the Crescent type necessitates the fastening of each ring to the piston block. Not only that there is some clearance between the rings lying in the same plane, but just near their ends they are not in good contact with the cylinder, the deviation of the actual from the theoretical curvature reaching its maximum at these points. The two other rings belonging to the same set, then must be placed in such a way as to break joint (*Fig. 6*), and, of course, the relative position of the four rings must always remain the same.

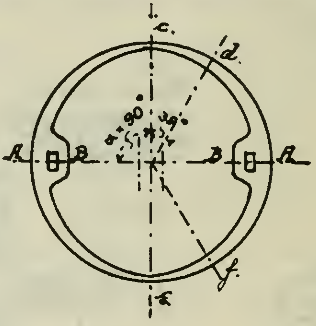


FIG. 8.

Generally, the rings are fastened to the piston by a special screw arrangement, which at the same time serves for readjusting the ring pressure. The ring carries at its heaviest part a boss (*a*) (*Fig. 7*), into which the head of a stay bolt is fitted. A wrought-iron T-shaped piece (*b*), serving as a nut for the threaded end of the stay bolt, is inserted into the piston. The head (*c*) can freely turn in the recess (*d*) and thus the ring will be moved away from or toward the center by turning the staybolt secured in its position by a lock nut. Besides taking up the reaction of the ring pressure, the stay bolt has to guide the packing ring. This latter purpose requires a rigid connection, and frequent readjustments as the ring wears off are indispensable for retaining the piston in good working order. Considering that the ring is supported only at one point and here rigidly, the free play of the spring action of its central part is considerably handicapped. Besides this, as four of these rings are required for each set, there are eight points of excessive pressure against only two, if a split ring, as treated in the fifth chapter, is employed.

The maximum bending moment is found at cross-section *A B, Fig. 8,* where

$$a = 90^\circ$$

then from Table No .1

$$M_{\max} = p\, r^2\, h \tag{9}$$

and hence the greatest tensile stress in the ring

$$f_{\max} = 6\, p \left(\frac{r}{t}\right)^2$$

The friction produced by the ring between its circumference and the cylinder walls will be

$$R = \mu\, (p\, h\, 2\, r)$$

where μ = coëfficient of friction; therefore the bending moment acting upon the stay bolt

$$M = \mu\, (p\, h\, 2\, r)\, .\, l$$

and the resulting fiber stress

$$s = \frac{\mu\, (p\, h\, 2\, r)\, l}{\cdot 098\, d^3}$$

Example No. 3.—For the steam pistons of the low-pressure cylinders in multiple expansion steam engines, often Crescent type packing rings are selected, owing to the large diameter required. These rings are cut off a cast cylinder of such a cross section as to make two rings at each cut, after they are severed at *c* and *e (Fig. 8).* This method has the advantage that the outside of each ring can be finished accurately, whereas a correct curvature of its inner surface is easily obtained by shaping the pattern properly. Turning the whole cylinder to proper size is all the machining necessary. The cross-section of the packing ring may decrease from 1¾ x 1¾ inches to 1 x 1¾ inches, the bore of the steam cylinder may be 7 foot, or $r = 42$ inches. If the ring shall produce a $p = 3$ pounds per square inch of wearing surface, the tensile stress will become

$$f_{\max} = 6\, .\, 3 \left(\frac{42}{1\frac{3}{4}}\right)^2 = 10{,}368 \text{ pounds per square inch.}$$

The outside diameter to which the cast-iron cylinder has to be finished before the rings are cut off is calculated from table No. 2.

$$\rho_{\max} = \frac{E\, r\, t^3}{E\, t^3 - 12\, p\, r^3} = \frac{18{,}000{,}000\, .\, 42\, (1\frac{3}{4})^3}{18{,}000{,}000\, .\, (1\frac{3}{4})^3 - 12\, .\, 3\, .\, 42^3} = 43{\cdot}17 \text{ inches,}$$

In order to lay out the inside curve, the ratio of the ring thickness t at any cross-section to $t_{\max}$ may be determined at first. Substituting equation (9) in equation (8) and combining both with equation (4), we find in a similar manner, as shown in a previous chapter,

$$\frac{t}{t_{\max}} = \frac{\sqrt[3]{\dfrac{12\, p\, r^2\, h\, (1 - \cos a)}{E\,.\,h\,.\left(\dfrac{1}{r} - \dfrac{1}{\rho}\right)}}}{\sqrt{\dfrac{12\, p\, r^2\, h}{E\,.\,h\left(\dfrac{1}{r} - \dfrac{1}{\rho}\right)}}} = \sqrt[3]{1 - \cos a}$$

and for different values of angle a the following:

TABLE No. 5.

a	$t =$	With $t_{\max}$ = 1·75″ t =	a	$t =$	With $t_{\max}$ = 1·75″ $t =$
90°	1.000 $t_{\max}$	1·75″	50°	·71 $t_{\max}$	1·24″
80°	·938 "	1·64″	45°	·664 "	1·16″
70°	·87 "	1·52″	40°	·616 "	1·08″
60°	·794 "	1·39″	35°	·566 "	·99″

In the last column of this table the thickness, at various points, of the packing ring under consideration is given. As the smallest thickness was fixed at 1 inch, the arc $c\ d$ and $e\ f$ will be concentric with the outside curve. The pressure exercised at point g or h amounts to

$$p = \frac{18{,}000{,}000}{12}\left(\frac{1}{42}\right)^8\left(\frac{1 - \dfrac{42}{43{\cdot}17}}{1 - \cos 5^\circ}\right) = 136{\cdot}6 \text{ pounds per square inch.}$$

VII. *The Double Ring.*—In treating the Crescent type some of its disadvantages were pointed out. The necessity of using four rings for each set in order to obtain a steam-tight joint between piston and cylinder is an undesirable feature. A greater depth of the piston is required, and in turn the weight of the oscillating mass is increased proportionately. Packing rings for large pistons must have a heavy cross-section, and since their breadth is limited by the depth of the piston, their thickness has to be increased.

Now it is obvious that a thin rectangular ring will be more elastic than a thick one of the same material, and if it is proved by practice that rings of a heavy uniform cross-section bear much harder on the extreme points at the cut and are not in contact with the cylinder back of this point, it is only a consequence of the stiffness of the ring at that point. With a thin ring of large diameter, however, we cannot exert the necessary pressure, because the stress at the dangerous cross-section would become too great. According to equation (A)

$$f = 12 p \left(\frac{r}{t}\right)^2$$

the unit stress increases with the square of $\left(\frac{r}{t}\right)$ *i. e.*, cylinder radius divided by the ring thickness.

A consideration of these facts has led to a design which retains the thin elastic packing ring and yet may be used in large cylinders. This is accomplished by using two concentric rings, *Fig. 9*. The outer ring is proportioned with the object of obtaining a flexible, uniform wearing ring, which assures a good contact with the cylinder. All the inner ring has to do then is to exercise a pressure upon the outer ring sufficient to prevent leakage of the steam. Steel or any other material of great elasticity may be used for it, as the ring is not in contact with the wearing surface of the cylinder. Cast iron or brass will answer the requirements of the outer ring. Both rings must be split and placed into each other in such a manner as to stagger the cuts, a dowel pin (z) holding the rings in their relative position.

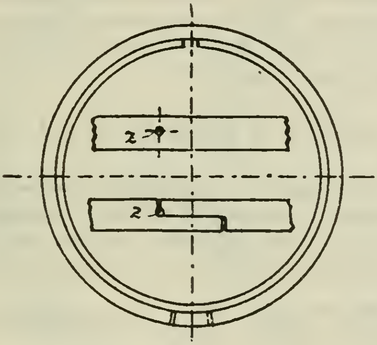


FIG. 9.

Example No. 4.—In order to fully illustrate the advantages of the double ring over the Crescent type, let us replace the packing ring referred to in example No. 3 by double rings. Instead of eight rings, two double rings of the same breadth, but lying in separate grooves, are now sufficient, reducing thus the space taken up by the grooves one-half. With the same but constant cross-section 1¾ x 1¾ inches and with the same tensile stress of 10,300 pounds for cast-iron, we get from equation *(A)*:

$$p = \frac{f}{12}\left(\frac{t}{r}\right)^2 = \frac{10{,}300}{12}\left(\frac{1\frac{3}{4}}{42}\right)^2 = 1\cdot49 \text{ pounds per square inch.}$$

The radii of curvature are, according to table No. 2,
for $a = 180°$

$$\rho_{\max} = \frac{18{,}000{,}000 \,.\, 42 \,.\, (1\frac{3}{4})^3}{18{,}000{,}000 \,.\, (1\frac{3}{4})^3 - 24 \,.\, 1\cdot49 \,.\, 42^3} = 43\cdot19 \text{ inches}$$

and for $a = 90°$

$$\rho_1 = \frac{18{,}000{,}000 \,.\, 42 \,.\, (1\frac{3}{4})^3}{18{,}000{,}000 \,.\, (1\frac{3}{4})^3 - 12 \,.\, 1\cdot49 \,.\, 42^3} = 42\cdot59 \text{ inches}$$

The diameter of the cast cylinder from which the rings are cut off is determined thus by $\rho_{\max}$.

The pressure exerted by the Crescent type ring amounted to 3 pounds per square inch; therefore, the inner or pressure ring has still to produce a $p' = 3 - 1\cdot49 = 1\cdot51$ pounds. Selecting steel of 1 x 1¾ inches cross-section, the greatest unit tensile stress will be

$$f^1_{\max} = 12 \,.\, 1\cdot5 \left(\frac{42 - 1\frac{3}{4}}{1}\right)^2 = 29{,}160 \text{ pounds per square inch.}$$

The thickness of the outer or packing ring proper is constant, *i. e.*, a parallel ring, as treated in Chapter IV, its inside forming a circle if placed in the cylinder. The outside diameter of the pressure ring is then 84 — 2 . 1¾ = 80½ inches, and the radii of curvature from table No. 2

$$\rho^1{}_{\max} = \frac{30{,}000{,}000 \,.\, 40\frac{1}{4} \,.\, 1^3}{30{,}000{,}000 \,.\, 1^3 - 24 \,.\, 1\cdot5 \,.\, (40\frac{1}{4})^3} = 43\cdot66 \text{ inches and } \rho^1 = 41\cdot81 \text{ inches}$$

If a cast ring is selected, a ring of variable cross-section (Chapter V) could be employed to advantage. Protected by the outer ring, this ring is not subjected to any wear, and, therefore, its minimum thickness at the cut can safely be reduced to about ¼ inch, giving practically a uniform pressure over its whole circumference.

VIII. *The Non-elastic Packing Ring.*—This type of piston packing ring represents a modification of the double ring. Take a ring of uniform thickness, turned to the same diameter as the cylinder bore, before it is split; then the split ring has no tendency of pressing outward against the cylinder walls; it is "non-elastic;" and the pressure necessary for a steam-tight joint must be produced and exerted upon the ring by some other means. If a second concentric ring, placed inside, is employed for this purpose, we have again a double ring, except that in this case the outside ring is without tension and does not contribute a share to the total pressure exerted by the combined rings. In cases where the use of a "pressure ring" is found inconvenient, special springs, called packing springs, may be employed instead. These springs, made either of steel or of German silver, are put into the grooves provided for the packing rings and held in place by headless screws or pins. As indicated in *Fig. 10,* the cut in the packing ring is covered by a plate (M) fastened on the inside in such a way that no steam can pass from one side of the piston to the other.

FIG. 10.

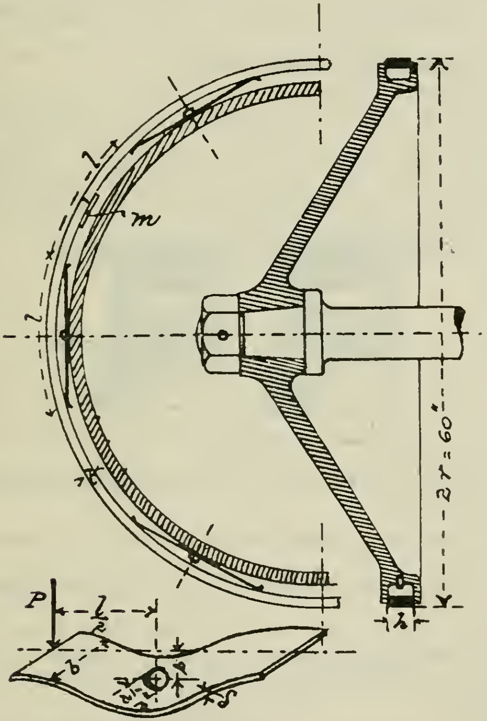


FIG. 11.

Example No. 5.—A 60-inch piston, shown in *Fig. 10,* is fitted with a cast-iron non-elastic packing ring carried by six packing springs *(Fig. 11).* The ring of a uniform cross-section 1 inch thick and 3 inches wide represents a continuous beam, supported at twelve points

$$\frac{(60 - 2\,.\,1)}{12}\,\pi = 15\cdot18 \text{ inches apart.}$$

Let us assume that a pressure of 3 pounds per square inch is required for a steam-tight joint; then each end of a spring must exert a force of $3 \times 3 \times 15{\cdot}18 = 136{\cdot}6$ pounds upon the ring. The stresses caused in the packing ring by these twelve single loads, which the elasticity of the ring must uniformly distribute over the whole circumference, can be computed with the well-known formulæ for a beam fixed at its ends and loaded at center. The maximum bending moment is

$$M_{\max} = \frac{W\,l}{8} = \frac{h\,t^2}{6}\,f$$

and the resulting intensity of stress in the packing ring

$$f = \frac{136{\cdot}6\;.\;15{\cdot}18\;.\;6}{8\;.\;1^2\;.\;3} = 518{\cdot}4 \text{ pounds per square inch.}$$

The same results may be obtained by putting

$$W = p\,.\,h\,.\,l \text{ and } f = \frac{(p\,.\,h\,.\,l)\,.\,l}{8}\cdot\frac{6}{h\,t^2} = \frac{3}{4}\,p\left(\frac{l}{t}\right)^2$$

The intensity of stress (f) depends upon the square of the free span (l) divided by the square of the ring thickness (t). As the packing ring itself shall not produce pressure : $\rho = r$, its outside diameter is equal to the cylinder bore = 60 inches.

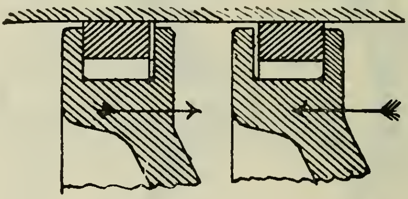


FIG. 12.

The springs may be proportioned as follows: The greatest bending moment acting on the cross section in the middle of the spring is $\frac{P\,l}{2}$

Deducting ½ inch for the pin hole from the width of the cross section and taking the safe working stress at 50,000 pounds per square inch for hardened steel, the required thickness (δ) is obtained from

$$\frac{136{\cdot}6\;.\;15{\cdot}18}{2}\;.\;\frac{1}{50{,}000} = \frac{(3 - \tfrac{1}{2})\,\delta^2}{6} \text{ or } \delta = {\cdot}223 \text{ inch, say } \tfrac{1}{4} \text{ inch.}$$

The ordinate at center of the unstrained spring must be

$$\varphi = \frac{6\left(\frac{l}{2}\right)^3}{b\,\delta^3}\cdot\frac{P}{E} = \frac{6\,.\,(7{\cdot}59)^3}{3\,.\,(\tfrac{1}{4})^3}\cdot\frac{136{\cdot}6}{30{,}000{,}000} = {\cdot}254 \text{ inch}$$

in order to produce the required pressure of 136·6 pounds.

IX. *The Spiral Packing Ring.*—The packing rings treated so far formed either a complete circle or a section of it, and accordingly the angle at center a varied either from 0° to 360° or from 0° to 180°, as, for instance, in the Crescent type. For reasons discussed above, all these rings must be cut open, making special devices necessary for stopping the leakage of steam through this cut and necessitating the provision of at least two sets of packing rings. If we connected several individual rings so as to form one continuous ring of as many coils, no cuts would be required. Another advantage especially valuable in engines with high piston speeds is offered by the elasticity of such a ring in a direction parallel to the cylinder axis. It presses the ring always against both rims of the piston block (*Fig. 12*), thus preventing the ring from alternately being lifted off one rim and taken along by the other one as the stroke changes. This constant play causes the excessive wear of the rims of some piston blocks, particularly if the rings are not fitted properly. As the ring now under discussion forms a spiral, this type of piston packing ring may be called the spiral packing ring.

The area of an infinitesimal element of the outer surface is $= h.\, r\, d\, \varphi$, and the pressure exerted by it $p\, h\, r\, d\, \varphi$. (*Fig. 13*).

Contrary to other packing rings, the depth (h) is not constant, but increasing with the angle at center a. Then the relation between h and h_1 (*Fig. 13*) is expressed by the equation

$$\frac{h_1}{h} = \frac{a - \varphi}{a} = 1 - \frac{\varphi}{a} \tag{10}$$

The bending moment at cross-section B will be

$$M = p \int_0^a (h_1\, r\, d\, \varphi)\, r \sin \varphi$$

or in connection with equation (10)

$$M = p\, h\, r^2 \int_0^a \left(1 - \frac{\varphi}{a}\right) \sin \varphi\, d\, \varphi$$

$$= p\, h\, r^2 \left\{ 1 - \cos a - \frac{1}{a} \int_0^a \varphi \sin \varphi\, d\, \varphi \right\}$$

$$= p\, h\, r^2 \left\{ 1 - \frac{\sin a}{a} \right\} \tag{E}$$

At point B the cross-section is $= h \,.\, t$, consequently the intensity of stress

$$f = 6\,p\left(\frac{r}{t}\right)^2\left(1 - \frac{\sin\alpha}{\alpha}\right)$$

an equation similar in form to that derived for the Ramsbottom ring.

After the first coil is completed and (h) has grown from zero (corresponding with $\alpha = o$) to $h = b$ $(\alpha = 2\pi)$ the depth

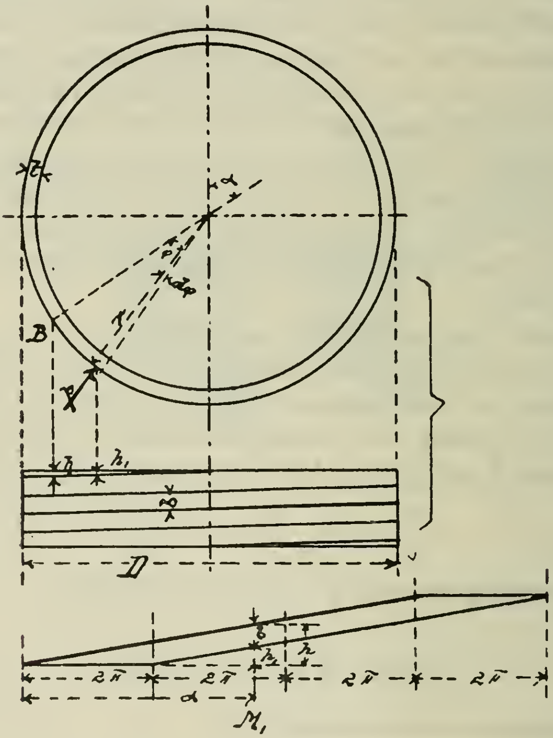


Fig. 13.

of the following coils is constant $= b$, until the last coil is reached for which the same relations hold good as for the first, h decreasing from b to zero. Equation (E) is therefore only good for these two coils, *i. e.*, between the limits

$$\alpha = 0 \text{ and } \alpha = 2\pi$$

From the accompanying figure it will be readily seen that all coils of uniform depth can be taken as difference between two coils of increasing depth which are rotated upon each other 360°. The bending moment acting on the second and following coils is then expressed by

$$M_1 = p\,r^2 \left\{ h\left(1 - \frac{\sin a}{a}\right) - h_1 \left(1 - \frac{\sin a}{a - 2\pi}\right) \right\}$$

or considering that

$$h - h_1 = b \text{ and } \frac{h_1}{b} = \frac{2\pi + a}{2\pi}$$

$$M_1 = p\,r^2\,b \left(1 - \frac{\sin a}{a}\right) \left(\frac{4\pi}{2\pi - a}\right) \qquad \text{(F)}$$

The radii of curvature of the various coils are derived from the corresponding bending moments in a similar manner, as shown in Chapter IV. The relation between M_1 and ρ is expressed by equation (7)

$$M = E.I\left(\frac{1}{r} - \frac{1}{\rho}\right)$$

where

$$I = \frac{b\,t^3}{12}$$

for a rectangular cross-section, t being constant for the whole ring.

The following table contains values of M_1 f and ρ for different cross-sections fixed by the angle at center a. It will be noticed that the bending moment for

$$a = \pi,\ 2\pi,\ 3\pi\ \ldots$$

is constant; it can be taken as an average value

a	$M =$	$f =$	$\rho =$	a	$M =$	$f =$	$\rho =$
$\frac{\pi}{2}$	$\cdot 36\,p\,r^2\,h$	$2{\cdot}16\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 4{\cdot}32\,p\left(\frac{r}{t}\right)^3}$	$\frac{5}{2}\pi$	$2{\cdot}02\,p\,r^2\,b$	$12{\cdot}12\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 24{\cdot}24\,p\left(\frac{r}{t}\right)^3}$
π	$p\,r^2\,h$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^3}$	3π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^3}$
$\frac{3\pi}{2}$	$1{\cdot}21\,p\,r^2\,h$	$7{\cdot}26\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 14{\cdot}52\,p\left(\frac{r}{t}\right)^3}$	$\frac{7}{2}\pi$	$759\,p\,r^2\,b$	$4{\cdot}55\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 9{\cdot}1\,p\left(\frac{r}{t}\right)^3}$
2π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^3}$	4π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^3}$

Example No. 6.—The spiral packing ring, shown in *Fig. 13,* shall fit a steam cylinder of 40-inch bore. It consists of four coils, and, if compressed, has a depth of 3 . ¾ = 2¼ inches. The cast-iron ring shall be so proportioned as to exert a pressure of 3 pounds per square inch, the average tensile strength (*f*) not exceeding 7,500 pounds per square inch. The cylinder from which the packing ring will be made by cutting a spiral groove into it must be turned inside and outside concentric, the required thickness being 1 inch, according to

$$7200 = 6 \,.\, 3 \left(\frac{20}{t}\right)^2$$

from table (6) as radius of curvature

$$\rho = \frac{20 \,.\, 18{,}000{,}000}{18{,}000{,}000 - 12 \,.\, 3 \,.\, \left(\frac{20}{1}\right)^3} = 20{\cdot}33 \text{ inches.}$$

The greatest tensile stress is reached at $a = \frac{5\,\pi}{2}$ where

$$f_{\max} = 12 \,.\, 12 \,.\, 3 \,.\, \left(\frac{20}{1}\right)^2 = 14{,}500 \text{ pounds per square inch}$$

and the corresponding radius:

$$\rho_{\max} = \frac{20 \,.\, 18{,}000{,}000}{18{,}000{,}000 - 24 \,.\, 24 \,.\, 3 \,.\left(\frac{20}{1}\right)^3} = 20{\cdot}66 \text{ inches.}$$

The clearance between the coils may have been made so large that the ring can be compressed 3 inches ($= \lambda$) until it is closed. If its outside diameter thereby is 40 inches, the force *P*, which must be applied, and with which the ring afterward presses against the rims of the piston block, can be computed with the formulæ for helical springs of rectangular cross section. It is

$$P = \frac{\lambda}{n} \frac{G}{3(\,b^2 + t^2)} \left(\frac{b\,t}{D}\right)^3 = \frac{3}{2} \frac{7{,}000{,}000}{3 \cdot 1{\cdot}56} \left(\frac{\tfrac{3}{4}}{40}\right)^3 = 14{\cdot}8 \text{ pounds.}$$

where λ the total compression of the ring,
n the effective number of coils,
D outside diameter of compressed spring,
G modulus of shearing elasticity.

The resulting stress due to torsion is found to be

$$f_1 = \frac{9}{4} \frac{P\ D}{b^2 t} = \frac{9 \cdot 14{\cdot}8 \cdot 40}{4\ (\tfrac{3}{4})^2} = 2{,}368 \text{ pounds per square inch.}$$

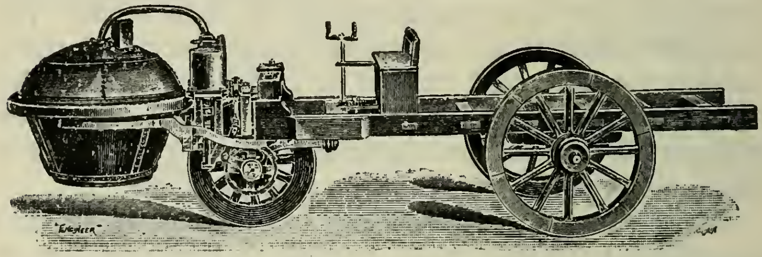
MOTOR ROAD VEHICLES.

By Joseph Sachs.

Historical.—Modern traveling facilities over fixed land routes have certainly reached a high degree of perfection. Every improvement in motive powers, conveyances and roadbeds is tried with a view to further increasing the safety, economical operation, speed, luxury and comfort of such conveying systems, until we almost feel that additional development, except in speed, would be excessive. In striking contrast, however, therewith, are our present modes of conveyance over ordinary roads. Here muscular power still reigns supreme, as it did ages ago; and while mechanical motive powers seem to find almost universal application in displacing animal energy, yet their utilization for the propulsion of vehicles intended to travel over common roads has never attained any particular practical or commercial prominence. Notwithstanding this fact, road vehicles so propelled even preceded the railroad locomotive. Steam-propelled road vehicles were amongst the very earliest suggested uses and applications of steam motive power and the modern steam engine.

Many were the pioneer attempts to successfully propel a road vehicle by steam energy. It is said that Sir Isaac Newton proposed a wheeled carriage which was moved forward by the reacting effect of a rearwardly directed steam jet issuing from a crude steam kettle on the vehicle. Joseph Cugnot, an officer in the French army, is however credited with having built the first really operative steam-propelled vehicle in 1769. Cugnot's motor vehicle had three wheels, the boiler and reciprocating piston engine being mounted on the front steering wheel, which was driven by a rachet gear. Following Cugnot's experiment came many others, amongst whom were Evans, in America, and Murdock, Symington and Trevithick, in England, who devised various more or less successful conveyances, propelled in most instances by reciprocating steam engines. Crude construction of engines and boilers and the meager information available on the subject was strongly apparent in these pioneer attempts. Many doubted the propelling ability of ordinary round wheels when turned by a self-contained motive power, and therefore devised vehicles which were propelled by means of rotating radial feet or arms, or pushed by means of rearwardly projected levers.

Many successful steam vehicles were, however, built and used, particularly in England. Active development was probably hindered by the rapid advancement of the steam railroad, and the enactment of certain English laws relating to the operation of such road vehicles almost stopped further progress in this direction as far as that country was concerned. The development of the motor-propelled road vehicle from then on was in the direction of large, slow-moving, hauling steam-road locomotives, which were used principally for agricultural purposes. Until within recent years these were the only successful and commercial motor road vehicles. Lighter and more rapid vehicles, intended to act as carriers as well, also appeared at various times. The development of the gas engine, electric motor and other light portable motive powers was a particularly important step in the advancement of self-propelled road vehicles of this type.



Cugnot's steam road vehicle.

It is unnecessary to speak of the development of the motor carriage or vehicle, other than the road locomotive, in Europe during the last decade. The various races and "meets," beginning in France in 1891, and followed by many others in this country and elsewhere, are also well known. Undoubtedly the time has now arrived when the problem must be attacked with the firm attempt to solve it in the near future. The tendency towards increased speed and economy in industrial and commercial directions undoubtedly demands a substitute for animal propulsion, and there are certainly a multitude of other reasons which recommend the mechanically propelled road vehicle for all other purposes.

Although the ideal motive power for this purpose is perhaps not yet available, many promising vehicles have been produced, including two-, three- and four-wheeled conveyances. While the problem depends greatly on the perfected portable motive power, yet it also involves many other important considerations. Some general features which need consideration are here presented. Light three- and four-wheeled vehicles, similar to various well-known types intended for the conveyance of goods or passengers, are particularly considered. Such mechanically-propelled vehicles must be considered from a radically different point of view than the horse-drawn conveyance, not only concerning the mode of propulsion, but also various other elements which are necessitated thereby.

The Motor.—Various portable motor powers are available, including steam, gas and electric motors and their various modifications. All of these have been practically applied, and motor vehicles at the present time may best be divided into these three classes. There are also other motors which have been experimentally tried for this purpose, but the results obtained with them have not been sufficiently successful to warrant serious consideration as yet, although some of them give promise of future success. Undoubtedly the selection of a motive power must depend greatly upon the use for which the vehicle is intended. While each form of motive power has certain inherent features, requiring special contrivances for its application, a motor for this purpose should meet certain general requirements.

The size and capacity of the motor necessary to propel a certain vehicle depend greatly upon the type adopted. Where the motor is capable of self-starting, speed changes and reversal, its connection to the driving wheels will be far simpler than where these features must be obtained by mechanism exterior thereto. In the former case, the motor may be of a smaller capacity than in the latter, where complicated gearing decreases the efficiency of transmission. The flexibility of the motive power adopted also affects the size of the motor required. A motor capable of exerting several times its rated capacity for short intervals has certainly a decided advantage over one which is easily stalled by an overload. In the latter case a motor larger than necessary to meet the ordinary requirements would be needed, owing to the necessity for sufficient capacity to meet sudden excess demands. Excessive capacity, however, in order to enable the vehicle to travel at extreme speed or to climb grades at maximum speed, is, however, to be discouraged. Aside from the danger involved in traveling in a self-propelled vehicle operated at unreasonable speed, the larger motor required would probably increase the cost and decrease the efficiency of operation under ordinary conditions. The motor should be capable of sudden spurts of power, yet it should always work, under average conditions, at as near its maximum load point as possible. American practice has been to use a gas engine of about 4 to 5 horse-power to propel a light carriage with from two to four passengers, at a fairly high speed. European carriages employ a somewhat smaller motor, which is permissible in view of the particular excellence of the roads. A smaller electric motor will in most cases propel a similar vehicle. Electric motors of about 3 horse-power normal capacity have been adopted in several successful vehicles.

Whatever form of motor is adopted, the conditions necessarily demand that it should be compact, give a maximum amount of energy with the least possible weight, be unaffected by the weather or hard usage, and entirely self-maintaining and automatic in its action. It must also be free from noise, odor and serious vibration, and the necessary fuel, whether coal, oil or the elements of electro-chemical change, must be cheap and readily procurable. If a reciprocating motor is used, the vibration will greatly depend upon its proper location and support, but primarily the reciprocating action should be balanced. The impulse of the pistons should also be cushioned and directed so as to least affect the spring-supported vehicle body.

Rotary motors, certainly, have great advantages over the reciprocating form.

Whether one or two separate motors are to be used is a matter depending greatly on the motive power selected. Double motors, separately operated, cost and weigh more, are less efficient than a single motor, and have advantages only when the motor is capable of self-starting, reversing and speed changes. With such motors, one connected separately to each driver will result in certain advantages which will be apparent when the gearing and steering mechanism is discussed. Where, however, the motor does not possess such features, their duplication is not to be advised.

Vehicle Frame and Body and Disposition of Mechanism.—Rapid traveling over uneven roads and the stresses and strains due to a self-contained motive power, driving traction wheels, necessitate not only a strong, although light construction, but also one which is particularly adapted to traction work. In some instances the motor and other mechanism have been placed in the vehicle body, which has been directly fitted with axles and wheels, to which the motor is suitably geared. In others a separate vehicle truck has been adopted, on which all driving apparatus is mounted, and which can be fitted with any suitable form of body. The latter construction seems to possess advantages. In the construction of such trucks tubular steel framing seems to have been generally adopted, although angle bars have also been used.

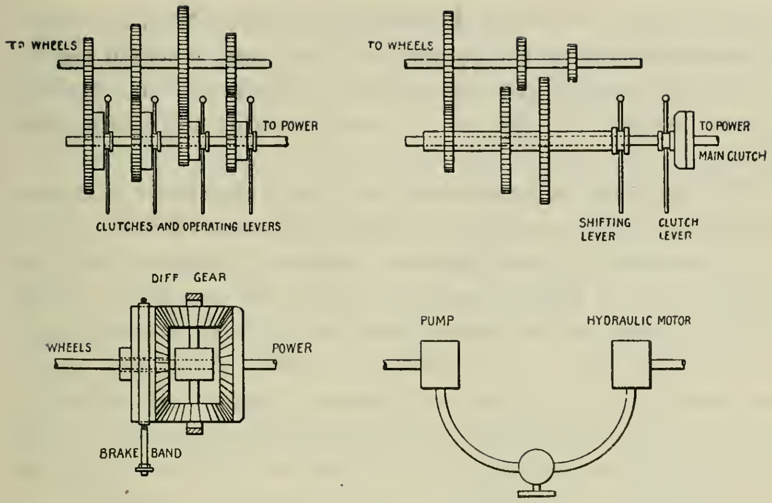
Neither the feather-weight nor the battering-ram type of construction will meet with approval. A motor vehicle is intended for ordinary usage. It is neither expected to resist the unusual accident nor to be adapted for traveling only over asphalt-paved avenues. The development of the bicycle has undoubtedly demonstrated the correct position on this point.

Whether the motor and mechanism is located in the body of the vehicle or directly mounted on a separate truck, its disposition (and also of the load to be carried) must be such as to produce not only tractive effect, but also to prevent top-heaviness. Safety in a vehicle moving at a rapid speed over rough roads and steered around sharp curves can only be secured by having the center of gravity of the entire loaded vehicle as low as possible. To produce the best tractive effects, it is certainly essential to properly weight the driving wheels, yet in many instances this point seems to have been more or less ignored. The location of the motor and mechanism over the steering wheels may not only prevent the operation of the drivers without slipping, but also increases the difficulty of steering. A proper relation should exist between the capacity of the motor and the tractive ability of the driving wheels. A motor having more energy than can be efficiently converted into vehicle travel by the drivers is a poor contrivance.

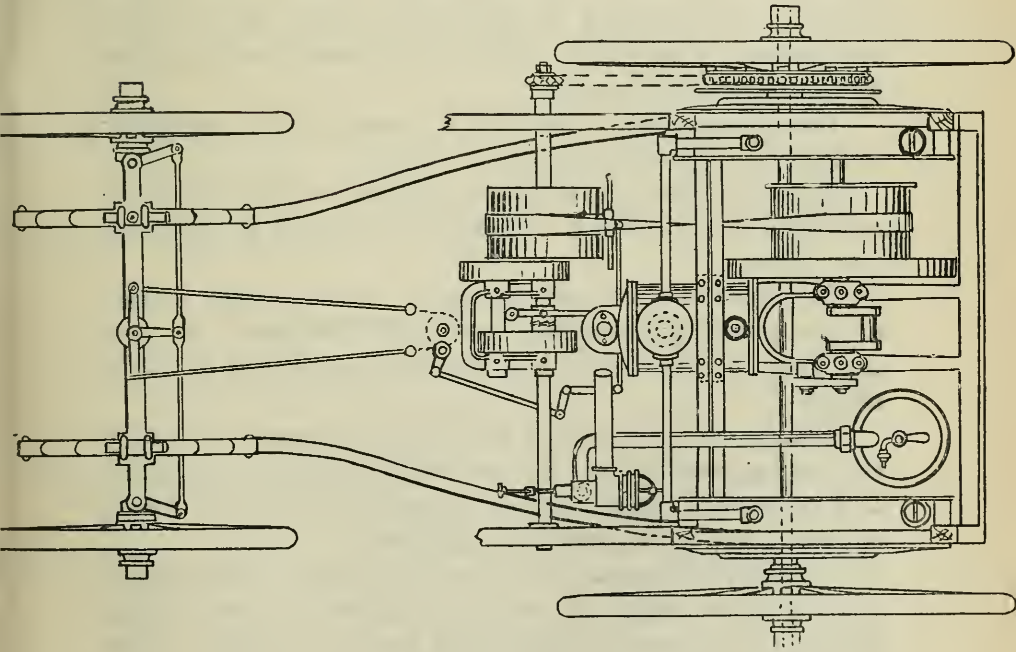
Gearing.—The simplest form of connecting the motor to the driving wheels is possible where the motor is inherently capable of self-starting in either direction and speed variations. With such motors the moving member would in its simplest form be directly connected to the driving wheels or axles. As this, however, is difficult of accomplishment, even with such motors, some simple form of gearing has been used, consisting of either an ordinary spur gear or sprocket wheel and chain connection. In such instances the gearing is but a minor consideration, consisting generally of but a single reduction, and whose efficiency, when properly constructed, is comparatively high. Where, however, the motor is incapable of inherently performing the functions above mentioned, the gearing between the motor and the driving wheels bears a most important relation to the motor, as it is this part of the mechanism which must be relied upon for this purpose. Innumerable arrangements of mechanical devices have been devised to serve as variable speed and reversing gears. It is a matter of great difficulty to eliminate complication and serious inefficiency from such mechanism. The larger capacity needed in the motors requiring such gears is largely due to the inefficiency of transmission.

Various devices have been used to produce the above-mentioned results, among which the following may be mentioned:

The transmission shaft is fitted with a number of spur gears which coact with corresponding gears on the driving shaft from the motor. Each of these gear sets is differently speeded,



Some variable-speed gears.



Plan of a German gasoline motor vehicle with shifting belt transmission.

and the gears on one of these shafts are controlled by means of separate clutches, the operation of any one of which rigidly fixes its respective gear to the shaft, which is then operated at that particular speed, or reversed through an intermediate gear.

Pulleys may be substituted for the gear wheels and connected together by means of straight and crossed belts.

A number of spur gears of different diameters may be mounted on a sliding sleeve, moving on the power shaft, which is controlled by means of a single clutch connecting it to the motor shaft. By shifting the sliding sleeve any one of the gears mounted thereon is meshed into a corresponding gear on the transmission shaft, which is then operated at the speed of that particular gear combination. For reversing, an intermediate gear must be used between the two shafts.

A friction disc, over whose surface a small friction roller, sliding on a keyed shaft, is moved radially to one side or the other of the center, and resulting in various speeds and reversal. A hollowing of the center of the disc or some mechanism to bring the roller out of contact with the disc serves for stopping purposes.

One or more belts controlled by means of idler pulleys or similar belt-tightening devices.

Friction rollers, on the driving and driven shaft, which are normally out of contact, but can be connected by means of idler rollers.

Various forms of hydraulic gears, which usually consist of some pumping mechanism operated by the motor, and forcing water or other liquid into a suitably connected hydraulic motor.

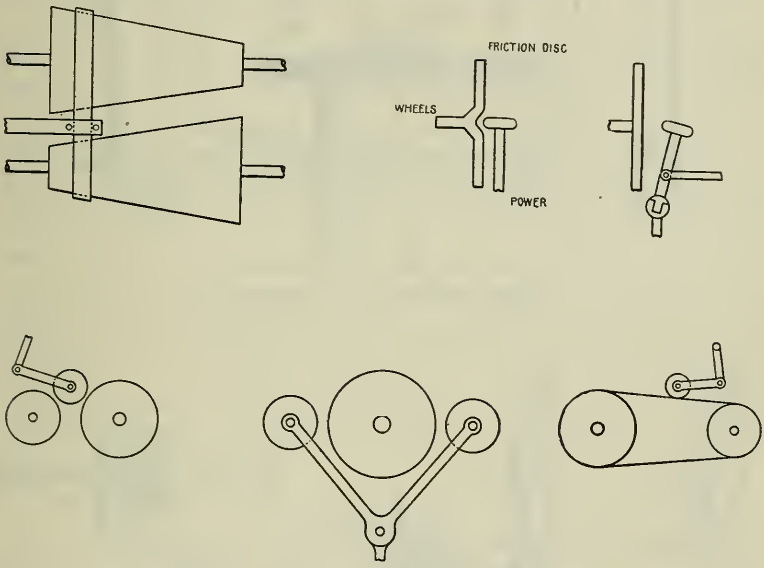
Friction roller devices, in which varying speed is produced by varying pressure between the driving and driven member, and reversal by means of two diametrically opposite rollers applied at will to the main driving roller.

A differential gear device, in which one side of the balance gears is driven, while the other is retarded by some suitable means, the connecting gear being used as a driver, whose speed is varied by varying the retarding force.

Cone pulleys with a single shifting belt.

The above examples of variable speed gears simply constitute a few of those that have been experimented with for motor vehicle purposes.

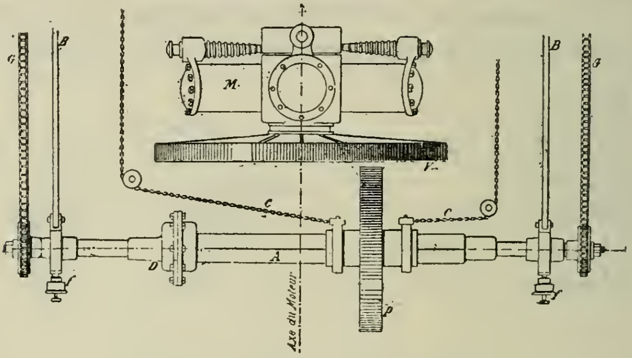
It is questionable whether numerous speed variations are essential. Although it is desirable to have two or three speed changes, the use of complicated gearing mechanism capable of a large variety of speed combinations is to be discouraged. The connection of the driving member of the variable speed and reversing gear mechanism to the driving wheels may be by either sprocket and chain or ordinary spur gearing.



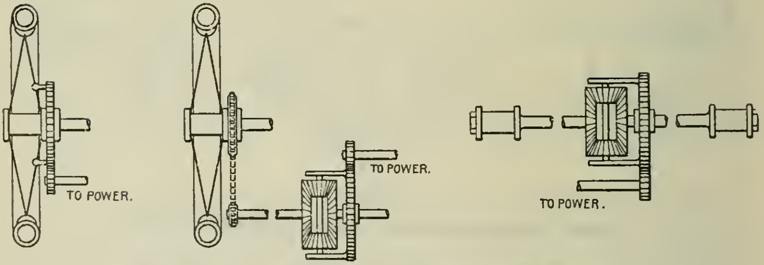
Some friction-wheel and belt variable-speed gears.

Front and rear driving wheels have been used. In going forward, it is to be noted that the reaction tends to throw the weight of the vehicle towards the rear; in the first case, therefore, on to the steering wheels and in the latter on the driving wheels. If both driving wheels are operated by a single motor, some method of compensating for the difference of travel of the outer and inner wheels in turning curves must be provided. A balance or differential gear, clutch or ratchet and pawl connection must be placed between the wheels, either in the rotating axle where the wheels revolve with the axle, or in the driving power shaft, where each wheel revolves separately on a fixed axle, and is independently driven. The variation in wheel travel can also readily be taken care of by means of separately driven driving wheels, the motors connected thereto being properly controlled to produce the desired effect.

The Wheels, their Construction and Function.—Not only must this part of the conveyance act as a support, but also as a propelling medium. It is, therefore, necessary that the construction should differ in many respects from that used in the present form of vehicles. Two forces are brought to bear upon the wheel construction, one due to the rotary twist of the motive power, and the other due to the side thrust and pressure in traveling over roads that are in any way otherwise than smooth. In order to resist the twisting action of the motive



LePape friction disc driving gear.



Simple and balance gear driving arrangements.

power, it is essential that the spoke should have sufficient strength on a plane with the rotation from the hub to the rim. To resist the side thrust pressure exerted through the wheel from its base to the hub, the construction must be equally strong in a direction at right angles. With the intention to, as far as possible, minimize the twisting action on the spokes due to the motive power, it has been found advisable to apply the driving power as near as possible to the rim of the wheel, and it would appear equally advisable to make the hub bearing with rotating wheels as wide as possible, to minimize the results of side thrust pressure.

Small wheel diameter is essential to reduce the height of the vehicle body. While in some instances radial wooden spokes and rims have been used, yet it appears that a metallic construction, involving tangent spokes and steel rims, is superior for many apparent reasons. This form of construction not only gives the maximum strength with the minimum of weight, but is also more in keeping with the entire mechanism. Side thrust pressure may exceed the strain exerted from the driving point to the rim. The necessary strength in this direction must therefore also be embodied in the wheel construction. A wooden wheel with broad spokes has advantages in this direction. There is, however, no reason why the same results cannot be obtained by a proper arrangement of metallic tension spokes.

Two plans are available for supporting the wheels at their centers, and both methods are applicable to both steering and driving wheels alike. One method involves the rotation of the wheel at the hub on a rigidly fixed axle. The other necessitates the fastening of the wheels directly to the end of the axle, which is then revolved in suitable bearings. Where the first method is used for the driving wheels, each wheel must be separately geared to a motor or some intermediate shaft. In such instances the balance gear is usually placed in the intermediate transmission shaft, which is suitably split, each half being connected to one side of the driven balance gears. Where some form of clutch or ratchet device is used to produce the necessary differentiation of travel in the two driving wheels, it is possible to directly apply such mechanism to the wheel hub between the driven member and the wheel proper.

Where the wheels are fixed to a rotating axle, two somewhat similar methods are also available, but only one of these is really practicable. This involves the splitting of the axle, preferable at the center between the two bearings, and connecting the two halves together by a balance gear mechanism, the central member of which is driven. It is also possible to use some form of clutch mechanism on both sides of a centrally driven power wheel. The other method involves a continuous rotating axle, which is driven by the motor and revolves in suitable bearings. The wheels are loosely fitted to each end, being held to the rotating axle by means of clutch or ratchet devices.

In adopting the fixed axle with rotating wheels for steering purposes, it is possible to use almost any form of steering gear hereafter described. In the case of the rotating axle with fixed wheels, however, it is practically essential to adopt a continuous axle from wheel to wheel, and therefore use some fifth wheel or its equivalent method of steering.

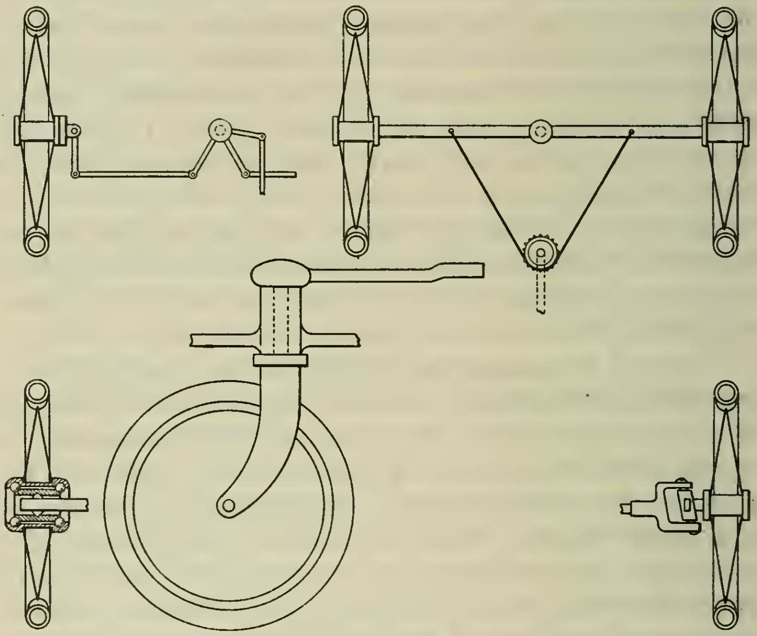
In order to produce the best tractive results, wheel-tires must be most carefully considered. Efficiency in this direction depends greatly, with certain fixed other quantities, not only upon the grip between the tire and the surface traveled over, but also upon its flexibility. Steel and rubber tires have been used. Results seem to indicate that certain forms of the latter type, particularly the pneumatic, are productive of the best results. Not only does this form of tire give greater comfort, due to its cushioning effect, but also superior tractive effects and the reduction of side thrusts in both drivers and steering wheels. This cushioning effect, by eliminating vibration due to other types, also effects great economy in the depreciation and disturbance of the mechanism.

The superior traction due to the material itself is no doubt an advantage, but the cushioning or give effect is particularly notable in considering the efficient operation of such tires over the ordinary roads. What is known as road resistance is greatly minimized by the use of tires having a slight give, instead of a rigid, unimpressionable surface. The ordinary road surface is made up of innumerable minor obstructions, closely following one another, and making a continuous track of inclines over which the wheel must be raised only to be lowered on the other side. Certainly this action occurs with great rapidity, even in traveling at ordinary rates of speed. Its effect has been experienced by all who have traveled over a cobblestone street surface in a springless wagon. With the ordinary rigid tire, where no give exists, the entire weight on the wheel must be lifted over this multitude of minor obstructions with a consequent greater expenditure of energy than if the vehicle were traveling over an appropriately smooth surface as compared with the ordinary road. It is true that, theoretically, part of this energy must be returned when the wheel descends on the other side. These minor obstructions, however, must either be crushed into the roadbed or surmounted. A similar action takes place where the road is more or less soft, allowing the wheel to sink, so that in revolving it must either crush down or surmount the incline in front.

With the pneumatic tire, the obstruction, instead of being crushed into the ground or entirely surmounted, is partly, so to say, pressed into the tire, which not only necessitates the raising of the vehicle over a much smaller height, but also gives the tire additional grip. The reduction of side thrusts, in a similar manner, is also to be noted. The striking of an obstruction on either side of the actual point of contact on the wheel base being partly taken up by the cushioning effect of the tire, less pressure will be exerted through the spokes. In the steering wheels this is particularly an important factor, as it greatly reduces the energy necessary to move them and facilitates their operation.

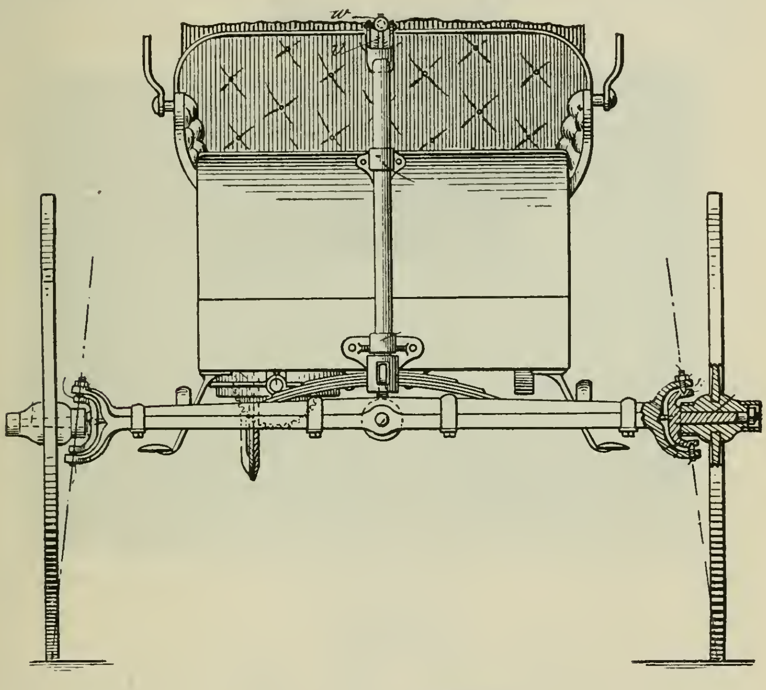
Pneumatic tires have therefore almost universally been adopted for this class of work. It is certainly essential that they should be impervious to ordinary injury, and should either be of a protected type, or have an ample thickness of material. It is also advisable, and apparently borne out by practical experience, that the tire should be given an ample base of contact.

Steering Wheels and Gear.—There is probably no more essential element to be considered in the construction and operation of motor vehicles than the steering mechanism. Under all conditions, and particularly at high speed, this part of the apparatus is of the utmost importance, tending greatly toward the ultimate safety of operation. It is essential, primarily, that the steering mechanism should be capable of easy and rapid operation, and yet should not be delicate or in any way affected, unless moved by the operator. Not only should the minimum of energy be required to vary the position of the steering wheels, but the movement of the operating device, in order to produce a certain fixed position of the wheels, should be reduced to a minimum.



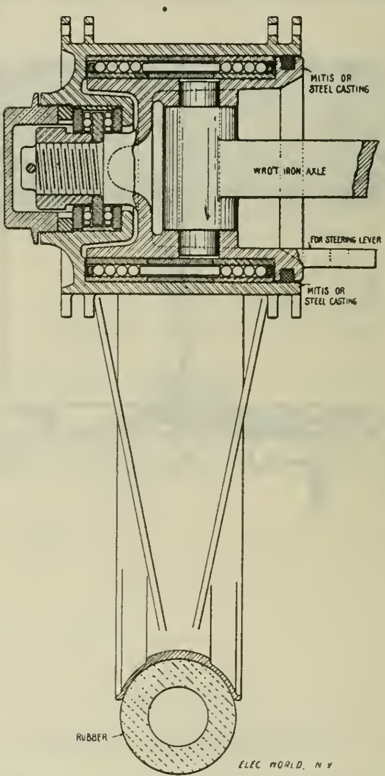
Steering gears.

When an obstruction is encountered by either of the steering wheels, the tendency is to throw that wheel out of its course, and consequently a strain is exerted through the steering gear, which must be counteracted at the operating device or elsewhere, in order to prevent the other wheel being similarly acted upon by the connecting medium between the two, and thus directing the vehicle out of its original path. Such actions are continuously taking place. Owing to this fact, and to the above-mentioned requirements, it is essential that the energy transmitted from the point of contact on the wheel base to the operating device be reduced to a minimum, and inversely when the steering wheel is to be operated from the operating device. Inasmuch as the steering wheels must be pivoted at some point, either independently or jointly at a center between the two, the principle to be observed is to reduce the length of the lever between this pivotal point and the point of contact on the wheel base to a minimum, which is certainly ideal when the point of contact is on a direct line with the pivotal line. With such an arrangement the effect above mentioned will be reduced to a minimum.



Steering gear of Duryea vehicle.

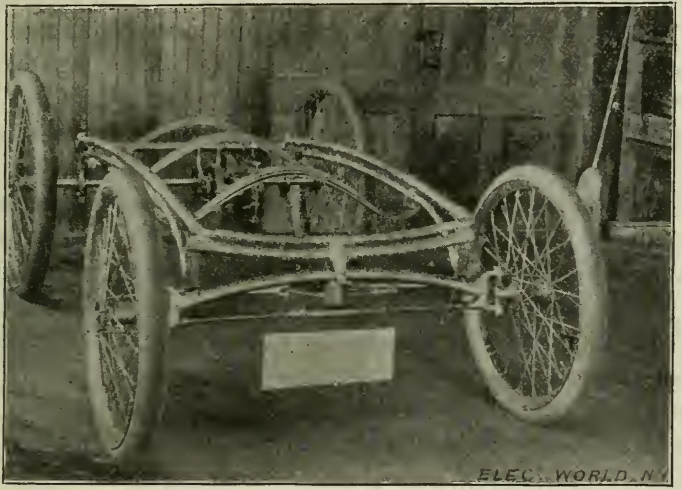
Various forms of steering mechanism are available, but one method in particular seems to have been favored in the practical construction of motor road vehicles. This arrangement consists of separate and independent short axles, upon which the wheels revolve, each axle being pivoted close to the hub in suitable forks at each end of a fixed axle-tree. Ordinarily the pivotal line is directly vertical, being brought as close to the contact line as possible. Another method is to have the pivotal line at an angle from the vertical, so that it strikes the contact line on the wheel base, and therefore eliminates all leverage between these two points. This last-mentioned method, however, results in a most curious appearance of the steering wheels, when in any other position except their nor-



Morris & Salom hub-pivoted steering gear.

mal. Another plan adopted, entirely eliminating the distance between the two points, is to pivot a sleeve, on which the steering wheel revolves, centrally in the hub, on a direct vertical line with the wheel base. Each steering wheel may also be supported in a separate centrally pivoted fork, similar to the steering gear adopted in bicycle construction.

The fifth-wheel plan, or the pivoting of the axle centrally between the wheels, seems to be somewhat at a disadvantage for this class of work, and has therefore not been adopted in many instances. It will be noted that with this type of construction the maximum leverage is obtained between the pivotal point and wheel base, and therefore the maximum energy would be required at the operating device in order to hold the steering wheels steady, unless suitable gearing is used to reduce this leverage by an increased movement of the operating device.



Tabular steel truck showing short axle steering gear of "Columbia" electric motor carriage.

For the operation of the steering gear proper, various combinations of levers and gears are possible. The simplest arrangement probably consists of a direct chain of levers and rods. Where an increase of movement is not objectionable in the operating device, an arrangement of gears giving a rotary movement, which is transformed into a straight line movement, has certain advantages. The steering gear may be operated manually by the operator, or through the medium of power mechanism. With the ordinary form of vehicle, as at present developed, hand-steering seems to serve all practical purposes, and has the prime element of simplicity and positive operation. With certain forms of motive power, however—electricity, for instance—the operation of the steering wheels by power mechanism might be productive of excellent results without greatly affecting the simplicity. It is advisable to arrange the steering gear so that the wheels are set at different angles in turning curves, in order to prevent scraping on the tire. Excellent results have, however, also been obtained by a parallel setting of the steering wheels.

Front and rear steering wheels have been adopted to conform to the previously mentioned arrangement of drivers. As it is essential to operate the steering wheels with a minimum expenditure of energy, the weight resting and thrown upon them should be reduced to a minimum, consistent with reasonable construction. Where the steering wheels are therefore so placed that they are excessively weighted, the steering contrivances would necessarily be less efficient than where the pressure on the wheels is not so great. With front steering wheels the track of the vehicle is at once changed and the pressure from behind assists the steering action. Where the steering wheels are located in the rear the tendency of the drivers to continue their forward movement would seem to result in a dragging effect on the former.

Some means of permitting a vertical oscillation of the steering wheels on a pivot central between the two wheels should be provided. This greatly facilitates the steering operation over rough roads and prevents any extraordinary disturbance of the equilibrium of the vehicle proper.

Braking Appliances.—It is also of prime importance to provide devices to efficiently and rapidly arrest the movement of the vehicle. Such appliances or brakes may operate at different points between the motor device and the wheel tires, and they may be operated either by hand, foot or power.

Mechanical braking appliances may be applied directly to the wheel tire, but in this case they must be of such form as to reduce the wear on the tire to a minimum. Certain forms of roller brake shoes have given very excellent results for this purpose. Applying the braking action, however, through the medium of either brake bands or shoes to a separate revolving brake pulley, fitted to some shaft between the motor and driving wheels, seems to be a frequently adopted form. Whatever form of mechanical braking appliances are used, they must be arranged to be equally operative with rotation of the wheel in either direction. The application of a brake band or shoe in the various forms of mechanical brakes, by means of a foot or hand-operated lever, is probably the simplest arrangement, and has been found quite ample for ordinary purposes. Here again, however, can power operation be employed with very excellent results. By power operation is meant not only the direct application of a motor device to the braking appliances, but their operation by the momentum of the carriage itself. This can be accomplished both mechanically and electrically, the latter method being considered in connection with electric motors.

(*To be continued.*)

PRELIMINARY COMMUNICATION ON "STELLAR DYNAMICS."*

BY LUIGI D'AURIA.

Editors Journal of the Franklin Institute:

Astronomers, since William Herschel, have recognized the study of the proper motion of stars, or "stellar dynamics," as the great problem of astronomy. Professor Simon Newcomb, when confronted with the proper motion of the now famous star 1830 Groombridge, which has been estimated at no less than 200 miles per second, his first thought was about the force in nature capable of producing such motion. He imagined this force in the combined attraction of all the stars of the visible universe, which, from observations, he estimated to be constituted by no less than 100 millions of suns, each on the average five times heavier than ours. The diameter of the universe containing all these suns he supposed to be equal to the distance passed over by light in 30,000 years. His calculations proved that if the star 1830 Groombridge had been attracted from infinity to the center of such universe, its velocity could not be more than one-eighth of the observed velocity of this star.

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*Under the above title the writer read a paper before the American Philosophical Society, May 13, 1897.

Since Professor Newcomb's estimate of the aggregated mass of the visible universe is rather liberal from a telescopic point of view, it would seem that gravitation cannot play a very important part in the phenomenon of the proper motion of stars. But then, can we suppose stars being original creations, originally projected in space with different velocities, in every imaginable direction? If we have to accept this view, we may as well say with the Mussulman, "God has willed it so," and dismiss any farther study of the subject. Fortunately, the scientific astronomer does not share in such fatalistic idea of nature, and therefore the subject in question still absorbs him almost to the exclusion of all others.

The first step towards the solution of this vast problem must be taken in the direction pointed out by Professor Newcomb, that is, we must first discover a force powerful enough in nature to account not only for the proper motion of 1830 Groombridge, but for a motion even greater than this. Without this force being first discovered, the problem must inevitably remain at a standstill. Where is this force to be found? Tyndall said that potential energy of gravitation is the original form of all the energy in the universe. The writer, firmly believing in this principle, thought, a number of years ago, that the interstellar ether, if possessed of the virtue of attraction of gravitation, might act powerfully enough upon the stars to give them their proper motion; but remembering the extreme tenuity of ether, he refrained from prosecuting the problem. How could a substance, estimated to be about

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times less heavy than atmospheric air, be more powerful than the 100 millions of suns, each five times heavier than ours, which Professor Newcomb had invoked to account for the proper motion of 1830 Groombridge? The force required to account for this motion must be, at least, 64 times greater than that derived from all these suns.

It was only recently that the writer, having overcome his reluctance to a certain degree, undertook the computations of the problem, and found, to his surprise, that the attraction exerted by the interstellar ether is powerful enough to account for almost any proper motion of stars. The motor was found in gravitation, acting through the same medium which nature employs for the transmission of light, heat and electricity. True, this discovery supposes ether capable of attracting matter by gravity, a fundamental question which unfortunately science has not yet settled;* but when we consider that the problem of the proper motion of stars, without this hypothesis, appears to look beyond solution, it would seem strange that nature should deny ether the attractive power of gravity, unless in doing so some great purpose was served. However, suppose that in the progress of science it should be found that some other natural, but unquestionable cause in nature, is responsible for the proper motion of stars, would the writer's investigation become fruitless? Certainly not, for the reason that failing in its original intent would indirectly settle the question that ether is gravitationless, and thus solve a problem of the greatest importance in physics.

Inspired by such promises, the writer, without making any attempt to work up the details of the problem, prepared a

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*Sir William Thomson, now Lord Kelvin, speaking of ether in his lecture on "The Wave Theory of Light" (see *Journal of the Franklin Institute*, November, 1884, p. 334), said: "We have no knowledge that the luminiferous ether is attracted by gravity; it is sometimes called imponderable because some people *vainly imagine* that it has no weight. I call it *matter* with the same kind of rigidity that this elastic jelly has."

short paper, under the title "Stellar Dynamics," which he read before the American Philosophical Society of Philadelphia, May 13, 1897. In this paper he proved that, given the ether the density as estimated by Maxwell, and the power of attracting matter by gravity, a body placed within the sphere of ether containing all the stars of the visible universe, and at a distance from the center of such sphere equal to that passed over by light in 2,200 years, would pass this center with a velocity equal to that of the star 1830 Groombridge, taking into account the attraction of the ether alone; and such body would oscillate about the same center, rectilinearly, with a period of a little over *seven million* years, which would be also the period of oscillation of every other star. This part of the problem was fully appreciated by Professor Newcomb in a note addressed to the American Philosophical Society of Philadelphia, dated May 19, 1897, in which, referring to the writer's attempt, he says: "It is not impossible that in the progress of science it may turn out to have a sound basis, so far at least as the fundamental idea is concerned. As such it would be of historic interest, and should be placed on record."

Without taking into account the mutual attraction of stars, the writer concluded that they would move in rectilinear paths in every direction. But considering such attraction, he has found that rectilinear oscillations would be incompatible, and that every surviving star would have to move on a more or less elongated elliptic orbit around the center of the visible universe, in one direction or the other.

PHILADELPHIA, PA., JULY 14, 1897.

NOTES AND COMMENTS.*

SCIENTIFIC BREVITIES.

Moissan and Dewar have lately announced the successful outcome of their joint experiments on the *liquefaction of fluorine*. The liquefaction was accomplished in Dewar's apparatus, at a temperature of —185° C. When a current of fluorine gas is passed into an apparatus maintained in the midst of liquid oxygen in tranquil ebullition at a temperature of —80° C., liquefaction does not occur. But as soon as that temperature is diminished by exhausting the gas above the liquid oxygen, the liquefaction of the fluorine begins, and a clear yellow and extremely mobile liquid is obtained, which resumes the gaseous state as soon as the temperature rises. This liquid has lost the chemical activity characteristic of fluorine in the gaseous state. It no longer attacks glass, silicon, sulphur or phosphorus. Fluorine at a very low temperature, however, still attacks carburetted hydrogen, and its affinity for hydrogen seems still to exist. M. Moissan and Professor Dewar are continuing their investigations, and although solid fluorine has not yet been obtained, M. Moissan is sanguine that this astonishing result will also be secured.——Prof. Dewar, in his concluding lecture on "Liquid Air as an Agent of Research," gives an interesting account of his observations of the *effects of intense cold* on chemical action. At very low temperatures, he declared, all ordinary reactions entirely ceased, largely because everything became solid—a state of matter not favorable to chemical action. Photographic action, however, persisted to a certain extent, particularly if gelatine plates were used. This might probably be explained as indirectly due to the property possessed by organic bodies, especially the more complex ones, of phosphorescing at low temperatures. Professor Dewar also showed how cold increased the magnetic moment of a permanent magnet by as much as 20 or 30 per cent., and at the same time illustrated the magnetic properties of liquid air itself. In conclusion, he referred to the effects of extreme cold upon living organisms. In the case of ordinary putrescent matter it was found that the spores were not killed by being subjected to the temperature of liquid air, and experiments were now being carried out to discover whether seeds exposed to liquid air for at least 100 hours still retained the power of germination.——Hartley and Ramage, as the result of spectroscopic study of a large number of ores and minerals, have made the interesting observation that a number of the so-called rare elements are much more widely distributed than has hitherto been supposed. *Gallium*, for example, was found in sixty-eight out of 168 specimens, occurring in most magnetites, bauxites and blendes, and nearly half the clay ironstones and manganese ores. Rubidium appears to be even more widely distributed, occurring in most iron ores. Indium was found in thirty minerals, including all the carbonates of iron and tin ores and most blendes. Thalium, while less widespread, was frequently found. Iron and sodium were found in every specimen, and potassium in all but two, one a blende and the other a tin ore. Calcium, copper and silver were found in all but a few cases. Such a wide dissemination of gallium and indium is unexpected, and the same might be said of silver. Among metals not looked for by the authors, titanium is known to be found almost universally, and possibly the same is true of gold. ——Dr. Waterville proposes *to obtain large and transparent crystals* of various substances by mounting a small crystal in a saturated solution in a manner so that it can be rotated on itself continuously with a speed of several rotations per second. Potassium and ammonium alums, copper sulphate and sodium chlorate are said to yield very fine results by this method.——A patent has been issued jointly recently to Alfred E. Hunt, of Pittsburgh, Benjamin Talbot, of Pencoyd, Pa., and Percival Roberts, of Philadelphia, on the use of *carbide of silicon in the manufacture of steel.* Carbide of silicon is made by the Carborundum Company, at Niagara Falls, by passing an electric current through a cove of sand mixed with coke. The finer and better grade is used as an abrasive, but there is produced considerable material which is not valuable for that purpose, and can be sold cheaply. It has been used experimentally at Pencoyd. It is split up and gives both silicon and carbon to the molten steel. It quietens and solidifies the metal and may become useful in the manufacture of castings and other specialties when solid metal is desired. It has the advantage over ferro-silicon, with 10 to 12 per cent. of silicon, because the silicon in the carbide is concentrated, the carbide containing about 70 per cent. of silicon and 30 per cent. of carbon.——Consul Germain writes to the State Department from Zurich, Switzerland, that the new addition to the *aluminum works* of the Neuhausen Company will, when in operation, add 2,700 kilogrammes to the daily output of aluminum. Further, the Neuhausen Company is building new works, with water power to produce 10,000 horse-power at Rheinfelden, Switzerland, and has also acquired water rights for similar purposes at Lend, near Gastein, in Austria. A German-American syndicate has planned the erection of works for the manufacture of aluminum at the waterfalls of Sarpfoss, in Norway. The water power there, it is estimated, will produce 10,000 horse-power, and the plant is to be ready for operation some time in 1898.

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* From the Secretary's monthly reports

A PROPOSED INTERNATIONAL TESTING LABORATORY.

From the *Engineering and Mining Journal* we learn that a circular recently issued by Dr. Herman Wedding, the eminent metallurgist, refers to the formation at the congress held at Zurich, Switzerland, in 1895, of the "International Society for the Unification of the Methods of Testing Materials of Construction." The council of this society has decided that in order to carry on its work to the best advantage the work hitherto done in many isolated places should be brought together in a common focus, when it could be classified, compared and reduced to a standard.

Such a central laboratory would also have the task of following the progress of both industry and science; of examining all new methods of any importance brought forward in various quarters; of searching for new methods whenever new problems were presented; and of serving as a guide to individual chemists. The establishment of a central laboratory of the kind indicated is far from being an easy matter. In the first instance, national feelings must be reckoned with. It has been universally felt that only a neutral country could be the seat of such an institution, and the unanimous choice fell on the city of Zurich, the intellectual capital of Switzerland, and the seat of the last congress, with scientific institutions of high standing, and furnished with a laboratory for testing materials of construction, erected on the most modern principles; while, on the other hand, no commercial jealousies could possibly be awakened by selecting a country devoid of ironworks of any magnitude.

Whatever place might have been chosen, the first difficulty arising would have been that of obtaining a proper locality for the central laboratory. Of course, it was out of the question to raise capital for building such a laboratory in a foreign country. But, fortunately, it has been possible to secure the use of ample accommodation in the magnificent chemical laboratory of the Fed eral Polytechnic School. The Federal Council has been pleased to grant the use of these rooms, free of rent, for the projected central laboratory, and thus the great difficulty of location has found its solution in the most favorable way. The next step, that of finding a fit and proper head for the central institution, has been successfully accomplished by securing the services of a most competent specialist, Hanns von Jüptner, chief chemist of the Neuberg Iron and Steel Works in Austria.

Only one step now remains to be taken; raising a fund for the maintenance of the central laboratory, that is, for the salaries of the director and his assistants, for the cost of reagents and other incidental expenses, and further, for remunerating the assistants of some eminent chemists in various countries, who have kindly undertaken to take part in the work proposed. For these purposes $10,000 per annum is required, and it would be impossible to start the laboratory unless the payment of this expense was secured for, say, ten years. There is no chance of obtaining these funds either by government grants or from the institutions existing in various countries. The only practicable way is, evidently, to obtain subscriptions from the ironmasters of the various important iron-making countries. Looking at the immense importance such a central laboratory is likely to acquire for the whole of the iron industry, and the very large pecuniary benefit ultimately following therefrom, it is suggested that large iron works might contribute, say $250 per annum each for that purpose. It is desirable to have these contributions come from as many countries as possible.

It may be mentioned that the firm of Krupp, of Essen, has already subscribed $250 per annum for this purpose, while the Austrian iron masters have made a handsome beginning by subscribing a sum of $1,750 per annum. All the other iron-producing nations, it is hoped, will follow.

It may be added that the results secured will be reported at the next meeting of the International Society, which will be held at Stockholm, in Sweden, on August 23d.

ARTIFICIAL PRODUCTION OF DIAMONDS.

Prof. Wm. Crookes gave the following interesting references to the probable origin of the diamond, and the efforts hitherto made to produce it artificially, in a recent lecture at the Royal Institution in London.

The lecturer stated that speculations as to the probable origin of the diamond have been greatly forwarded of late years by improved means of obtaining high temperatures; and through the successful experiments of Moissan, microscopic diamonds have been made in the laboratory. He had provided a most powerful dynamo, especially made for the purpose, weighing 4½ tons, and when driven by a 50 to 75 horse-power engine generating a current in the electrical furnace of 700 to 800 ampères at 70 volts, yielding a heat of from 3,500 to 5,000° C. In the process of making diamonds, the first necessity was to select pure iron and to pack it in a crucible with pure charcoal from sugar. Half a pound of this iron was then put into the body of the electric furnace and the arc formed close above it to utilize the electrical current passing through it. The iron rapidly melts and saturates itself with the carbon. After a few minutes it is heated above 4,000°—a temperature at which the lime of the furnace melts and volatilizes. The current is then stopped, and the crucible is plunged beneath the surface of cold water, where it is held until it diminishes to a dull-red heat. The sudden cooling solidifies the outer layer of iron, and holds the inner molten mass in a tight grip. The expansion of the inner liquid in solidifying produces an enormous pressure, and the dissolved carbon separates out in a transparent dense crystalline form - in fact, as diamond. Then commences the more tedious part of the process, the attacking the metallic mass with solvents to liberate the diamonds, the crystals of graphitic oxide, carbonado and bort—the cleansing operations being repeated until all the well-washed grains are collected and examined under the microscope. The laboratory diamonds burn in the air before the blow-pipe into carbonic acid, and in luster, crystalline form, optical properties, density and hardness are identical with the natural stones. Many circumstances, he pointed out, led to the conclusion that the diamond of the chemist and the diamond of the mine are akin as to origin, and that the diamond genesis must have taken place at great depths, under enormous pressure. Molten iron could have held the carbon in solution, and all the varieties of carbon crystals, and even the different tints of diamonds from various mines and geographical areas, could be accounted for on this theory. It is certain, from observations made at Kimberley, corroborated by the experience gained in the laboratory, that iron at a high temperature and under great pressure will act as the long-sought solvent for carbon, and will allow it to crystallize out in the form of diamond—conditions existent at great depths below the surface of the earth. But it is also certain, from the evidence afforded by the Arizona and other meteorites, that similar conditions have likewise existed among bodies in space.

PAINT AS A PROTECTION TO METALLIC STRUCTURES.

The Department of Public Works of New York City is about to carry out a test of the preservative qualities of various kinds of paint which should be of the greatest interest to all engineers and builders, and should provide them with some much-needed data. We learn from the *Scientific American* that the experiments are to be made on a massive steel viaduct which carries One Hundred and Fifty-fifth Street across the elevated tracks of the Manhattan Railway Company. The test is to be carried out in a thoroughly scientific and practical manner, and great care will be taken to shut out any disturbing element which might affect the value of the results. A tight board roof will be built beneath the viaduct to shield it from the smoke of the locomotives. The first operation will be to clean off all the old paint and rust by means of the sand blast, and this will be done until the surface of the metal presents a clean and bright appearance. The paint will be put on within three hours from the time the cleaning is finished.

The various manufacturers will be invited to tender bids and provide specimens of their paints, and these samples will be used in painting the structure. The precautions which are being taken will insure that the different varieties of paints will have the same opportunities to show their good qualities, and the results will be watched with close attention by those who are responsible for the erection and preservation of all classes of structural steel and iron work.

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MACHINE SUBSTITUTES FOR THE COMPOSITION OF TYPES BY HAND.*

BY HAROLD M. DUNCAN.

Viewed as one of the arts of design, printing has survived several distinct epochs of alternate exaltation and abasement; viewed as a mechanic art, its progress has been slowly but uninterruptedly towards increased perfectness of machinery and the acquirement of means whereby production is simplified, increased and cheapened. The developments of fifty years have been particularly revolutionary. A complete transformation has been wrought in original methods. The untiring inventive genius of the past several centuries effected its changes slowly at first; but to-day these are being inaugurated with such bewildering rapidity that the equipment of a modern printing office is antique long before the machinery comprising it is worn out. What is true of printing is true of the contemporaneous arts. The progress of one exactly parallels the progress of all industrial arts. There is an unremitting tendency to diminish the demands made by production upon the intelligence of the source of energy—which, in all handicraft, resides in the workman, and in all machines to a greater or lesser degree in the increased exactness of the motions therein embodied. It is the aim of modern invention to eliminate intermediary processes lying between the unworked material, in a raw state, and the finished industrial output. Nowhere is the correlation of formerly isolated functions better shown than in the giant rotary presses, which deliver miniature Niagaras of newspapers into the bins of the metropolitan dailies for distributing to the reading public. Printing, folding, inserting, pasting, recording and delivering are some of the combined performances of these machines, all automatically accomplished, in perfect synchronism, and at lightning speeds.

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*A lecture delivered before the Franklin Institute, February 26, 1897.

The supremacy of machine methods in printing is past mere hypothesis; alterations have taken place in almost all departments of the art. The functions of the compositor have alone resisted the assaults of invention. Why have not change and improvement succeeded in modifying the process of setting up types by hand? Apparently, type-setting is not a difficult operation. Observe the compositor at his case, composing stick in hand. One by one he lifts the letters from their respective compartments in the case and places them side by side into the stick, in the order of their use. Type follows type and line follows line until the stick is filled and its composed contents transferred to the galley, when the process begins again. Habit has rendered each function instinctual, and centuries of usage have canonized the practices of the art. In the precise way that the compositor of to-day does the work did the compositor of 400 years ago do it. There has not been a single radical change in the methods of the fraternity in all that time. Moreover, such influences as have been engendered by typesetting machines on the one hand, and by matrix-setting and casting machines on the other hand, are yet too embryonic to have become essentially alterative. Upon a conservative estimate not more than 3,000 machines of all kinds are now in use in the United States, and of this number a large proportion is centralized in the offices of great dailies. The number of compositors amounts to more than 125,000, and they are increasing at the rate of 3,000 each year. Outside of isolated printing offices, here and abroad, it is only within the last ten years that machine substitutes for the composition of types by hand have been regarded as practical enough to justify attention on the part of the progressive printer. Certainly it is not because inventors have disregarded the problem or because the requisite talent has lain dormant. For seventy-five years attempts have multiplied to accelerate the process of type-setting, either by machines for handling foundry-made letter or by machines for doing away entirely with the manipulation of types thus made. In Great Britain, since 1822, several hundred patents have been taken out for this class of invention alone; in the remaining parts of Europe the number is in advance of this; in the United States a still greater number is recorded. Of all this immense expenditure of inventive talent, mechanical skill and, it may be added, of the funds needed to carry on the various experiments, the machines which have reached commercial stages may be numbered on the fingers of one hand. With such and with their archetypes it is the intention to deal, but only from the standpoint of principles, to which mere mechanical details will be strictly subordinated. The extent of the subject forbids more.

NATURE OF THE PROBLEM.

Why are the practices of type-setting crystallized, and why were type-composing machines so tardy in achieving practical efficiency? The truth is that, while apparently a very simple process, type-setting is, in reality, just the opposite. Its requirements are of a mental kind, and the part played by manual skill is of a secondary rather than a primary character. The hand of the compositor is but the servant of his mind; the latter indicates the road the first must travel in. Were copy all alike, were types all of the same size and style, were words never divided at the end of the line, were lengths of lines an indifferent matter, it is more than probable that the first attempt to build a suitable mechanical substitute would have been successful. Lines, however, must be of approximately identical lengths among themselves in each measure employed; words will stubbornly refuse to occupy the given space; and type bodies cannot but vary setwise—from that bearing the full point and narrowest character to that bearing the widest character—in each size. One font also differs from another font in breadth to accord with the requirements of larger or smaller faces, and here the variation is bodywise. There is thus a two-fold variation, first as to width, second as to thickness. In length, all types are made to a supposedly uniform standard, which, with the American founders, ranges between ·918 and ·920 inch. An allowable deviation of one-half thousandth of an inch is not infrequent. Any height-variation exceeding this, either above or below the standard, is rejected.

Seven operations belong by rights to type-setting by hand. The compositor must (1) decipher his copy; (2) attend to its orthography and punctuation, according to the rule of the office in which he is working; (3) convert it into types and spaces; (4) uniformly apportion his spacing; (5) make-even his lines; (6) effect his corrections from proof-read sheet; (7) distribute his assembled types after they have served their use, either in printing or in electrotyping and stereotyping. These are the functions of the man, but are by no means all the essential factors to good type-setting. Neither in their entirety do they map out the machine problem. If the inventor does not aim to accomplish more than the assembling of the types and spaces and their ultimate distribution, his task ends with providing mechanisms to do what the compositor does in his work at the case. If the inventor aims to provide a printing surface of letterpress, in which he makes his own types or substitutes therefor, his desiderata extend beyond the domain of the compositor's art into that of the typefounder's. There are esthetic and mathematical considerations here to be dealt with.

A piece of first-class letterpress has three attributes, the presence of which ensures its excellence. These may be briefly enumerated. The first is evenness of impression, the lack of which in our newspaper printing furnishes its own commentary upon typographic deterioration. An even impression requires a surface the variation in parts of which shall neither require compensating for at the press by excessive make-ready nor manipulation of another kind. It is this exactness of height from foot to face of the types that permits of fine results in printing from foundry-letter of the best class.

The second requirement of good printing is perfectness of face, or unbroken continuity of line and curve over the entire surface which is to contact with the paper. This needs no amplification.

The third generalization is accuracy of alignment, the least departure from which fatally condemns a bit of printing as the fault of the workman who locks up the composed types into the printing-form, or else as the fault of the types themselves. In a word, the sin is either that of the stone-hand or of the material. This attribute of good printing requires the most accurate proportion and squareness of angles in the body of each letter that is used. If not to an approximate extent a perfect rectangle, the individual types comprising a line will not fit with the mutual closeness needed in a tight line; if not rectangular throughout their entire length of body they will "wabble" and rock. The same may be said of the feet of the types; they must be a perfect level, so far as practical perfection extends, and occupy a plane that is exactly at right angles with the plane of their sides.

Given the present conditions of publishing, it seems patent that under no system ever conceived will a preliminary functioning by intelligence be dispensed with in machine-work. There will always have to be operatives—at least as long as there is copy to be interpreted, bad grammar to be dealt with, and the caprices of writers for publication to complicate original manuscript.

Generally speaking, therefore, the task set the inventor in the field thus far traversed is to produce a machine which will translate copy into properly spaced lines, pages, or galleys of lines of types. Each of the broad classes of machine substitute with which printers are at present familiarized has approached the question from opposite standpoints. Broadly considered, these machines fall into two classes, viz.: machines which handle foundry-type, and machines which not only compose the printing surface, but go further and make the types of which, whether singly or in lines, such surface is made up. The first class takes in all systems of type-setting, and relates to those machines in which the mechanical functions only partially cover the accomplishments of type-composition as manually practised, and in which, as a consequence, the chain of operations merely runs parallel with one or more parts played by hand labor in the finished product.

Into the second class of machine substitutes fall those machines in which the chain of operations transcends manual methods and includes all the functions necessary in accomplishing a letterpress printing surface. As mechanisms, these latter are evidently far broader in scope than the first class of machines for type-setting proper. Whatever may be the excellencies or defects of their product, which will be later considered, they embody systems of original character, which step over the limits of imitative processes. In them, the kinematical chain—that is, the series of motions, not only in themselves considered, but linked together with relation to consecutive processes and a well-defined end—is lengthened by augmentation of new motions, each with a view to enlarged efficiency. If these machines can be kept within the boundaries of reasonable proportions, and can be made to conserve the proper standards of quality, then they are undoubtedly the fittest to survive, being the most complete. In the words of a great German mechanician (Rouleaux), "the most complete machine is that which best fulfils its own share of the work and has for this share the greatest proportion of the whole task." Such a standard will afford a safe criterion of judgment in analyzing various systems.

The Archetypal Patent.—The first patent taken out for a mechanical type-setter was that of Dr. William Church, a native of New England, who went to Great Britain, in 1821, to introduce a printing press. In 1822, he patented a system for casting, composing and printing types. Some English pamphleteers have said that as far back as 1797 one Herhan, in England, proposed a scheme which underlay the archetypal form of composing machine, and that he applied for British letters-patent. A careful search of the records reveals no trace of the invention.

Dr. Church was the first to propose the keyboard idea, which, at some point or other of the operation, now pervades all classes of modern machinery in this field. Attempts have been made to dispense with keys, but the machines, while ingenious, have fallen below the level of efficiency exacted in practical work, and since made possible by digital skill, either wholly or partially used.

The Church machine comprised three parts: First, a machine for casting the printing types,and also of arranging them in boxes of letters, so that the types of the same denomination were placed side by side in ranges, ready to be transferred to the composing machinery. The second part was a machine for selecting and composing the individual types into words and sentences. The third part was a process of printing and of delivering the sheets in a pile, thus involving a third machine. Distribution was no doubt to be effected by throwing the used types into the melting pot and recasting them.

After casting his individual types, which were delivered in rows and stored in separate upright receptacles in the composing machine, Dr. Church provided mechanism to bring them into assembly. Each row of types was located directly over a slot in a bottom plate, and had a device, somewhat like the jacks of the old-time harpsichord, to keep the opening closed. By depressing a key the corresponding letter was forced out of its magazine into a race. When the type was in the race, it was conveyed by collectors to a common center, where the beat of a small lever forced it down an aperture into a curved channel, along which it was fed in a continuous line. Spacing-even and other operations were done by hand. It is curious to note the breadth of the Church conception, for its period, although the intervals between the stages prevented the combination of processes from having practical bearing.

In the office of the London *Times* there is now employed, or was up until very recently, a method which is peculiarly similar to the Church procedure. The Kastenbein type-setting machine, one of the guide-plate class—later to receive attention—is used. Ordinary types are handled, but a large part of them is not distributed, being remelted and cast into new types at a machine from which the letters emanate in long lines, set for position in movable tubes, attachable to the type-setting machine. A distributing machine is also used at intervals in connection with the work.

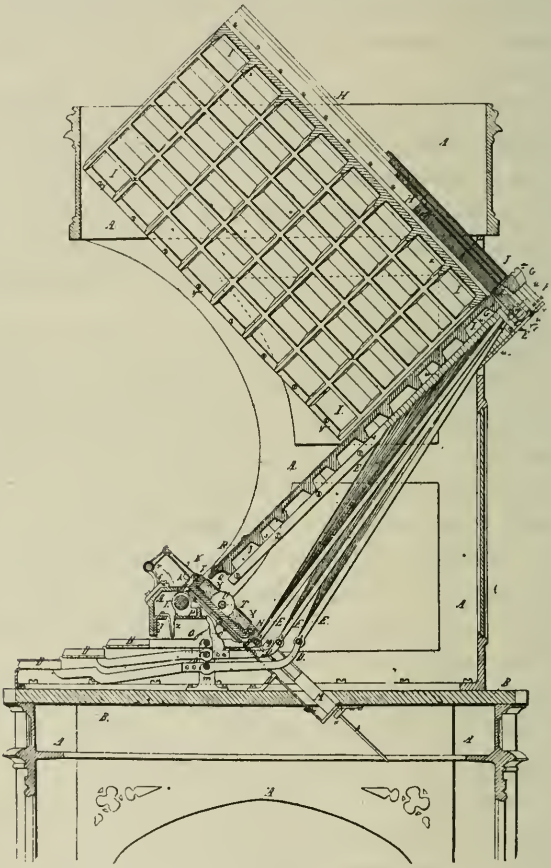


FIG. 1.—Young & Delcambre machine. Vertical side section.

TYPE-SETTING MACHINES.

Gravity and Guide-Plate Machines.—The most extensive variety of type-composing machines comprises those in which gravity is the principle and a guide-plate is the means to bring the types from their chambers to a common assembly-point. This basic conception arose in 1840, being incorporated in an invention by James H. Young and Adrien Delcambre, of France; it underlies every machine in which gravity is utilized. Illustrations of the machine will facilitate a comprehensive understanding of the principle. A vertical side section, some details and a front plan are shown.

The Young & Delcambre type-setting machine is one of a class extremely large as to numbers. The horizontal bed-plate *B* (see *Fig. 1*), located in the middle framework of the machine, has bearings *m* attached to it, carrying pins *C* which form the axes for keys *DDD* (like piano keys) to vibrate upon; three rows are visible. The ends of these keys are connected by the joints *8* to the inclined levers *EEE*, on the upper part of each of which are fixed inclined wedges *FF*. These act against the pushing-frames *GG* to force the types out of the chambers *HHH*, as shown in *Fig. 2*. The latter consist of parallel brass bars, raised one above the other, forming open channels, down which the types slide freely onto an inclined plane *J*. The guide-plate is seen at *JJ*, but the front view (see *Fig. 3*) displays it better. It is simply a grooved metal plate, placed in an inclined position, which received the types immediately upon

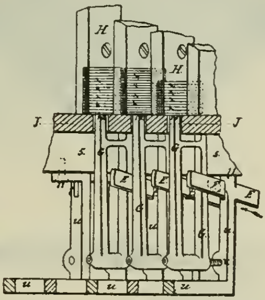


FIG. 2.—Young & Delcambre. Detail showing pusher-frames.

their being ejected from their chambers and conveyed each of them by its corresponding groove down to cross channels *n*, by which they were guided into the composing stick *K*.

Travelling Belt and Disk Machines.—Another fundamental invention, patented in 1853 and 1857, by W. H. Mitchel, a brother of the Irish patriot, is next in logical order. It also is archetypal. Mitchel's machine was the first type-setting machine to come practically into use. John F. Trow, of New York, used twelve of these machines in 1855, although the work was irregular and comparatively unsatisfactory. Mr. Pasko, Librarian of the New York Typothetæ, says that he saw and operated one of the machines in 1859, and that the distribution was faulty, but that the compositor made about 4,000 ems an hour speed. Outside of Trow's, no other office is known to have used the machine in this country.

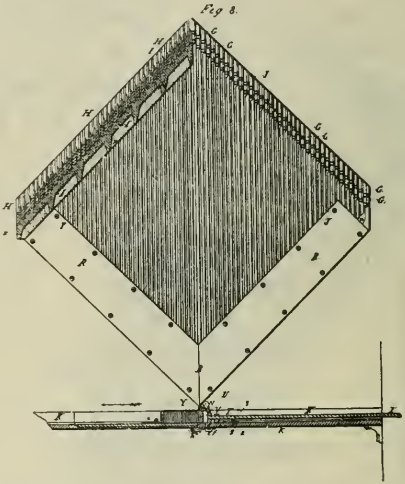


FIG. 3.—Young & Delcambre. Front view of guide-plate.

The view presented in *Fig. 4* is of the Mitchel composing machine. You will note that the employment of gravity is minimized, and that travelling belts of different lengths effect the delivery of the types in the order dropped by the finger-pieces. The resident principle is basic with all machines in which belts, disks and kindred reciprocating mechanism are used to bring the composing units to a common assembling point. The types are stored in the chambers *g*, the inclination of which is almost vertical to effect rapid descent. The application of power to the pulley *k* rotates the shaft *l*, which has around it a series of endless belts *m*, increasing in length toward the delivery end of the machine and passing over the rest-bars *n* and around small pulleys *i*. Each belt rotates from one of the type-magazines. The depression of the keys effects the release of the types onto these tapes, which carry them through the chute *x* to a diagonally-travelling belt *o*, passing around pulleys *37* and *39*. The types enter fair upon the center of this tape, by which they are carried with great rapidity (face to the operator) to the roller *39*. They then slide down the conductor *q*, between guide-bars *v w*, fixed on the composing-table, and run along in a continuous line under the eye of the justifier, who cuts off the length needed for a line, spaces

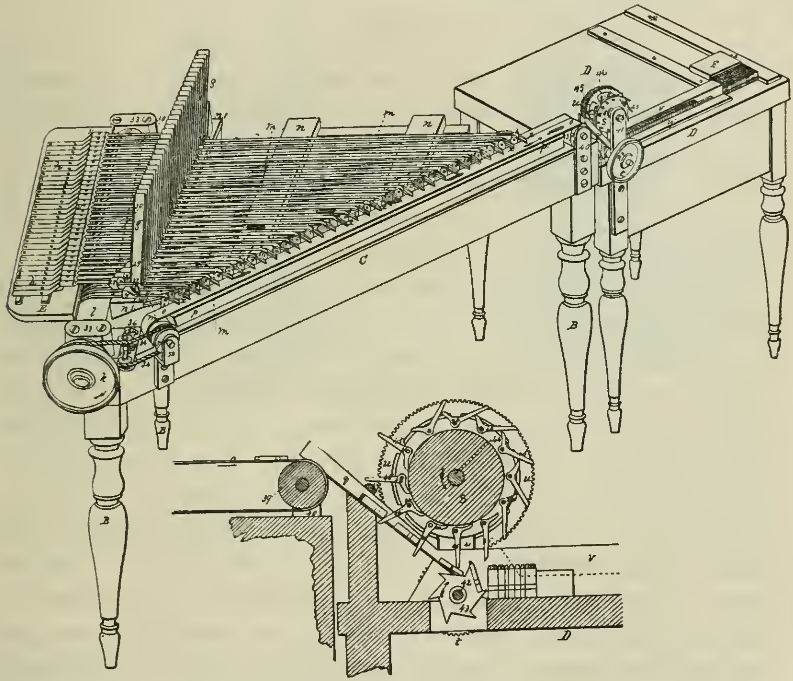


FIG. 4.—Young & Mitchell's machine. Vertical side view and section of conductor.

it to measure, and ranges the lines into galley *F*, upon a slightly inclined plane.

In the ideas explained, as fundamental to the Young & Delcambre machine and the Mitchel machine, we see the principles upon which all machines of the type-setting varieties have been based. Whatever of originality has been infused into more modern apparatus lies either in the better adaptation of mechanisms or the modified forms of devices. All employ gravity to some extent, and either the guide-plate or the traveling media in combination therewith.

MECHANICAL TYPE-DISTRIBUTION.

Having cognized the principles of mechanically setting types, there is an important operation next to be considered. Being expensive in themselves, types bought from the foundry must be re-used and placed back again in the magazines of the composing machine for continuous re-assembly. This is the second stage of the problem.

Mechanical type-distribution, or the separation of composed types into those of identical denominations, arranged in proper order for the composing machine, is generally accomplished by mechanisms forming a separate machine in themselves. Throughout all automatic distribution runs the same principle, that of selective affinity. The types must be specially nicked on their bodies so as to conform to wards in the channels to receive them, the "a's" having a combination alike among themselves, but different from the "b's," and so forth. The principle is that of the Yale lock. The nicks on the type form a key which will only fit the wards of the magazine it is designed to occupy. Suggested in 1840 by Gaubert, the idea has been applied and elaborated in many later machines, being now used in all such systems.

MODERN TYPE-SETTING MACHINES.

The Thorne.—Disregarding machines which have not reached the commercial plane, and omitting the half-dozen or so outclassed machines still used in a few offices in Great Britain, two modern type-setting machines—or systems—

present themselves. These are the Thorne and the Empire, formerly known as the Burr machine. The Empire is a gravity and guide-plate machine; the Thorne is a gravity and travelling-disk machine. They will therefore illustrate the latest forms of their respective principles. In both machines specially nicked types are employed for distributing purposes, and only in the Thorne are the composing and distributing functions combined in the same machine.

The Thorne type-setter and distributor, front and rear outline views of which are shown in *Figs. 5* and *6,* represents a development beginning about 1865 and lasting until the machine was marketed in 1889 or 1890, if memory serves me aright. It is a rotary machine, carrying the types in ninety vertical channels *D* around the periphery of a cylinder and extending its entire length. The mechanisms are in two parts, an upper movable cylinder *A* and a lower stationary cylinder *B,* placed on a common axis, the upper being the distributor and the lower the type-setter. The channels are nearly as deep as the type is high, and a trifle wider than the body of the type

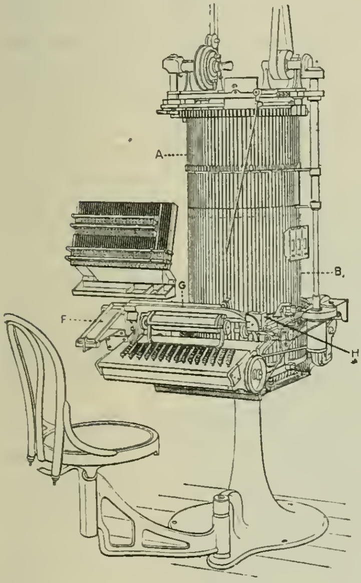


FIG. 5.—Front view of Thorne machine.

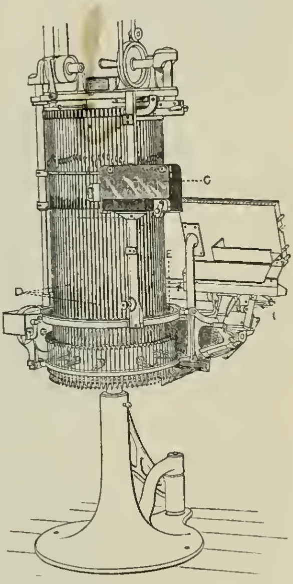


FIG. 6.—Rear view of Thorne machine.

to be contained. But one size of type can, accordingly, be set in the machine. The types lie in their channels, face out, and the letters are the same as ordinary foundry-letter, each character, space and quad being nicked at five points on their bodies, opposite the foundry-nick. The grooves of the distributing cylinder are indiscriminately fed with types at the sides by means of the peculiar form of feed-galley *C*, shown in the rear view, the lines being inserted without regard to order until the matter has all been fed into the chambers. The cylinder then rotates with an intermittent motion, and the harmonizing nick of each type contacting with the proper projections in the lower cylinder directs that letter to its proper groove, thus restoring the types to their respective magazines.

Composition is effected at finger-keys, of which there are ninety, one for each type-channel in the cylinder. A key is depressed and leverage causes a plunger to thrust out the bottom type upon a rapidly rotating disk *E*, with line of travel from right to left of the machine. The types are delivered to an endless belt and conveyed to a device *H*, which lifts each letter to a plane *G*, where the line is forming along a race-way, whence it is pushed forward to its place. An operator converts the continuous line into justified matter.

The feature of novelty in the Thorne machine lies in the application of the rotary principle, out of which arise compactness, rapid travel and apparent simplicity. The relationship, yet independence, of the distributor was a new application of an old idea. The mechanical means contain whatever of novelty there may be in the machine outside of the features treated upon.

The Empire.—The Empire type-setting and distributing machine is a comparatively recent outcome of very long experimentation. It divides with the Thorne machine the commercial patronage of those printing offices which, because of competition, an inherent distrust of line-casting machines and a desire for excellence in product, have sought in machines for handling foundry-letter the way out of their troubles. It embodies no new principles *per se*, and with the exception of a small cam, revolving at high speed in the receiving type-channel to drive the types forward as they drop, the weight of the letters and the direction of a grooved plate are the only means of bringing the types to the composing point. Distribution is effected in a separate machine, by means of specially nicked types.

The types, comprising eighty-four characters, of each of which a large number is provided, are contained in separate channels in three magazines at the top of the composer (see *Fig 7*). These cases have glass fronts, through which the faces of the letters may be seen. They may be removed when empty and filled cases substituted. To the rear of each channel at its foot is a steel plunger *A*, shown in the small diagram, *Fig. 8*. The actuation of a key brings this plunger against the foot of the selected type, in the manner shown, forcing it out of the channel into a groove in the guide-plate belonging to it. This groove directs its course downwards, on a plane inclining backwards, to a pendulum gate, and through the latter into a race where a continuous line of types is forming. A rotating cam drives each letter forward as it drops, and the

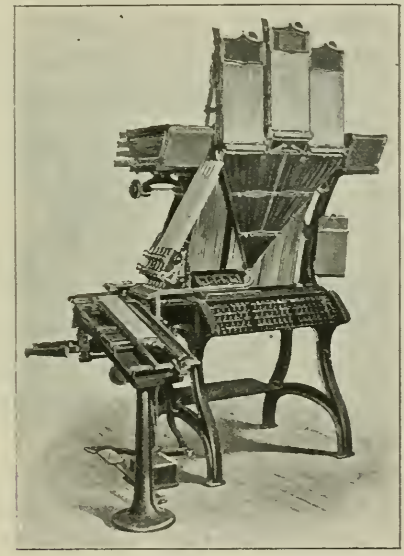


FIG. 7.—Perspective view of Empire composing machine.

line is thus kept moving toward a second operator, who is to justify the composed matter.

The guide-plate in the Empire machine differs in form from that shown with the Young & Delcambre machine, and comprises eighty-four converging grooves cut into a metal plate. This is an improvement, for whereas with the Young & Delcambre guide-plate the descending types had two planes of travel, in the Empire guide-plate they have but one. The principle is alike in both. A glass cover is provided for the entire grooved surface of the Empire guide-plate, the angle of backward inclination given the plate permitting the glass to form the bottom of each channel.

With the Empire, as with all machines of its class, the justifying function resides in an extra operator, whose work is done by hand, and whose speed determines largely the permissible rapidity of keyboard operation. Owing to superior facilities in the way of mechanisms for furnishing spaces, the justifying speed is enlarged.

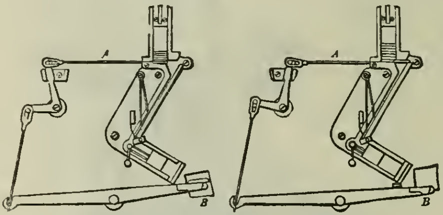


FIG. 8.—**Release mechanism, Empire machine.**

Although the types are not positively manipulated in the process of setting at the Empire machine, and wear is thus reduced, they are actuated by direct and forcible means in the distributor. A perspective view of this machine is given (*Fig. 9*), and a detail or so. One of the latter (*Fig. 10*) shows a single member of a series of type-carriers and also one of a series of slide-devices for selecting the nicks (*Fig. 11*), each of which has nick-pins adapted to enter the exposed nicks of its own particular type (see *Fig. 11a*). The page of type-matter is laid on the galley, and pressed by a weighted follower toward the machine. The first line is lifted by an elevator plate into a channel and is pressed into the machine by another weighted follower. The first type is cut off by a vibrating mechanism, is received by the type-carrier, gripped and held there by a spring, and passes on in front of each feeler-slide. If the nicks in the type do not correspond with the nick-pins, the types pass on. If they do coincide, they leave the carrier, go forward into a channel in a guide-plate, and are led into a chute which conveys them to the appropriate channels in the case below. Broadly stated, this covers the procedure.

JUSTIFYING BY MACHINERY.

The Cox Machine.—One of the principal functions of type-composition, whether done by hand or at the machine, is that of making all lines exactly even in length to the measure determined upon. This is effected in hand-setting by the use of spaces of different widths, of which there are five, ranging from the em space, which is theoretically the square of the body, to the thin space, which is one-fifth of the em. By substituting thin for thick spaces it is obvious that a line may be narrowed, while by the opposite process the line may be spread out. Any permutation can thus be made, within approximate limits. To do this by hand becomes almost instinctual; to accomplish it in the machine is quite a different thing. No type-setting machine on the market embodies such a performance; in all of them justification has still to be done by hand

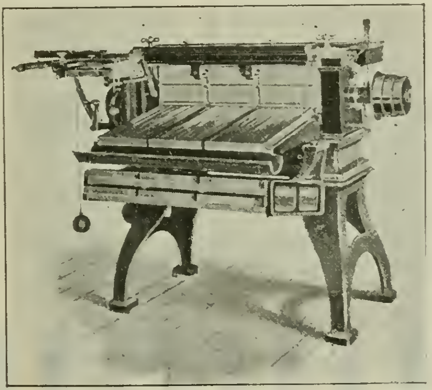


FIG. 9.—Empire distributor.

in the usual way. Few inventors of machines dealing with movable types have attempted it; for it is very apparent that an undue complexity must characterize any really efficient mechanism which has to deal with the constantly variable spaces between words. The Paige machine, in which the bulk of Mark Twain's fortune was expended, justified automatically. Mr. McMillan, whose machine was talked of about five years ago, published his solution of the problem about that time. His method was the continuous elimination of unsuitable spaces and the replacement of them by spaces adapted in size to the justification needed, and this until the line was evenly spaced out. The McMillan type-setter composed a continuous line of types. This was fed into a justifying machine, thin spaces having been inserted during the composing operation. Mechanisms separated this line into sections, each slightly less in length than the intended length of the justified line, a wire or stem, longer than the type, being placed at the end of each section. The section was clasped in a holder, capable of expansion to the required length of line, but no farther, and devices were actuated for forcing the thin spaces from the line, successively introducing thicker ones in their places, and repeating this operation with other spaces of the next greater thickness. The process was to be mechanically continued un-

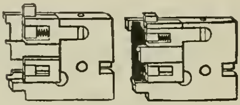


FIG. 10.—Type-carrier, Empire distributor.

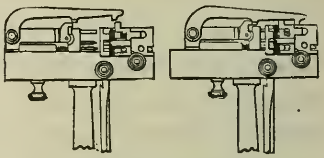


FIG. 11.—Slide device, Empire distributor.

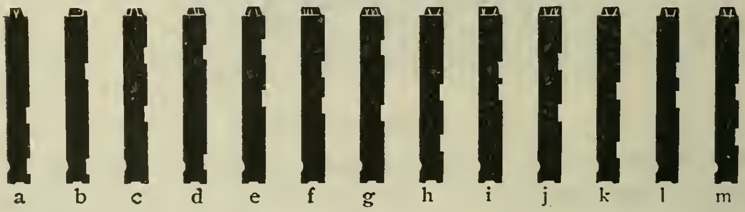


FIG. 11*a*.—Nicked body types for Empire machine.

til the line was adequately spaced-even. As is evident, this required a separate machine. As neither Paige nor McMillan machines bid fair soon to reach a commercial status, it is unnecessary to consider them.

Within recent months a Western type-foundry, that of Barnhard Bros. & Spindler, has fostered the rumor of a new type-setting machine. They have such a machine in experimental operation. It is proposed to set and justify movable types in the same machine, and thereby reduce the operatives by one man. Inquiry has developed this machine to be the invention of P. F. Cox, a brother of the inventor of the Cox Duplex Press, whose patents, issued in 1894 and 1895, exhibit the devices to which, as the latest proposals, attention is now directed.

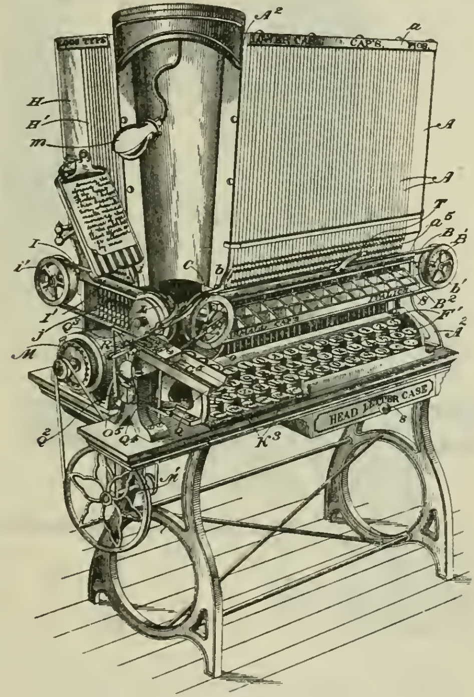


FIG. 12.—Front view of Cox composer.

Judging from the plan view here shown (*Fig. 12*), the Cox machine is seen to be a combination of gravity and the travelling-carrier principles, the type-channels being in duplicate groups, one with reservoirs for the upper- and lower-case letters, points, and so on, the other for syllable- and word-logotypes, of which six are noted upon the keyboard. The types are ejected directly from the channels *A*, upon a horizontal carrier-belt, *B*, conveyed to a chute *C*, through which they drop into a race-way or galley, an electrical alarm notifying the operative when the line has reached the point where justification is to begin.

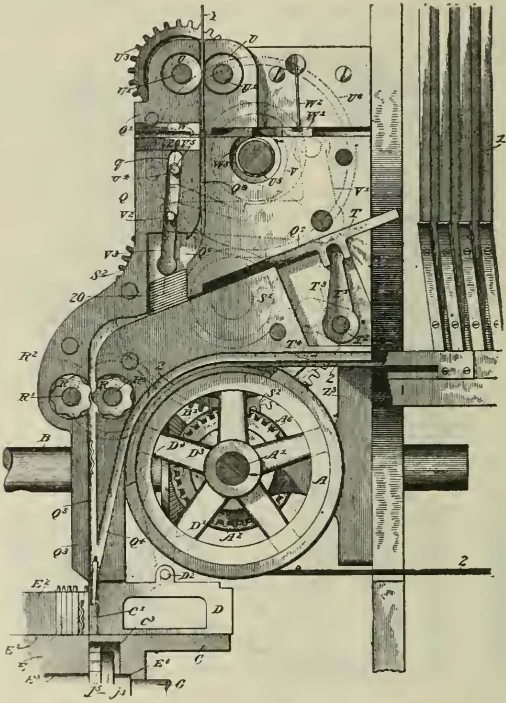


FIG. 13.—Sectional view of Cox justifier.

A similar series of mechanisms running at right angles with the first provide for setting up the logotypes. The electro-motor *M* actuates the machine, and by manipulating an electric switch between the motor and the wires the operator can stop and start the operations at will. Cases for small caps, italic, and head-letter are provided, from which, by hand, the requisite characters are inserted. The most novel part of the machine, however, is the provision for making-even. This was doubtless suggested by prior devices, such as elastic spaces—an old proposal—and possibly by the Shucker's wedge used in the Mergenthaler Linotype machine, for instance. Discarding the ordinary straight spaces, the inventor (see *Fig. 13*) employs a spool, not shown, carrying a continuous strip of lead Y, which is suitably non-resilient and when compressed will retain its form and not spring back. This leaden ribbon is conducted downward, cut into proper lengths, and fed into the reservoir Q^6. The cutting mechanism W is controlled by the amount of spaces in the reservoir. Upon depressing the space key, these lead strips pass through the rapidly revolving crimping rolls RR, are corrugated to a thickness equal to that of the en space of the type font, and pass down into their place between the words of the line. The operator continues until the bell rings. He depresses another key, thus removing the line of types which you will perceive must be over-spaced. A block moves a defined distance, according to the width of line, compressing the line of types and spaces lineally, after which it is passed into the galley. A machine for distributing has recently been patented. It is understood that the drawings here reproduced are merely offered as illustrating the principles used by Mr. Cox, and not the form of his machine for practical use.

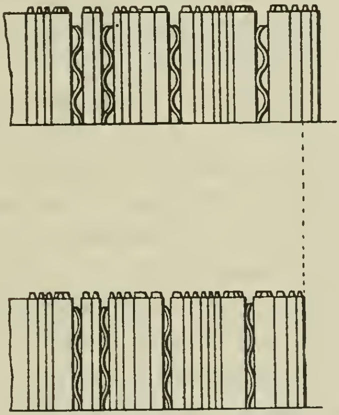


FIG. 13*b*.—Crimped spaces, Cox justifier.

Critically viewed, the proposed machine incorporates one novel principle, that of crimped spaces (see *Fig. 13b*). The difficulties to be anticipated abide both in the machine and in the product. An exact synchronism must be accomplished in the motions of the mechanisms, the conveyors running at right angles must be accurately timed with the spacing and the justification, while the amount of friction and consequent wear on the types will increase with the positivity of their manipulation. In the lines, as justified by corrugated lead spaces, pressure in a tight lock-up will be unequally resisted by the varying number of spaces in the lines, and this will cause the form to loosen and the types to lift or get off their feet at press.

CRITICAL CONCLUSIONS.

We have thus before us the complete series of machines belonging to the class of type-setting machines, and can now consider the principles generically.

It has been asserted that to obtain good printing no other material can be employed than foundry-made types, in the production of which extreme care is observed. This will have due consideration later. The question arising at this point is purely technical, and involves difficulties and drawbacks which inhere to the systems themselves, viewed as a whole. Type faces are a very costly part of the equipment of a printing office, and are a perpetual sinking fund for profits. It is self-evident that the original investment in body types, which cost from 30 to 50 cents per pound, is robbed of its earning power in exact ratio with the wear and tear outside of that caused by normal usage. To this original investment, about 8 per cent. must be added for extra nicking. It is also apparent that such small objects as printing types, varying among themselves as to size, in every font, set-way, must be handled both by delicate and precise mechanisms before a machine for assembling and distributing them can be satisfactory. Witness the failures of hundreds of inventions in this class, and the seeming abandonment of even the best of them by the vast majority of printing offices to-day! Witness their slow advances! What are the reasons? Partially because the fragility of the objects they are designed to manipulate engenders distrust of their economy; partially because the requirement that the machines shall handle all widths of letter from the thick m to the thin full point renders the mechanisms inexact and admits the element of chance; mostly, however, because their range of operation has not warranted printers in installing them. The hope is profound that machines in very different lines will better solve the problem. In all type-setting machines, and at some point of their travel, the types are necessarily held, actuated, or propelled forward by more or less positive means, thus engendering friction. Gravity alone is friction-inducing; springs to hold the types, or gripping devices, are still more so. Contrary to accepted opinion, it is not in the number of mechanisms that the real difficulty of such machines resides, but in the exact coördination of movements which must be very delicate yet positive in operation. The types must be brought from different points of storage to a common receiving point without transposition in transit, must be protected from contact of their faces with the surfaces over which they pass and from rounding of their edges at sides or feet; they must be entirely manipulated by mechanisms in setting and again handled by mechanisms in distributing. If they can be satisfactorily justified by machinery a third factor of wear is presented, while a still further extension of precise machine-motions is necessary. Beside these considerations there is one that decidedly militates against machine efficiency. Printing types are subject to a diverse industrial use. After being printed from, they must be restored to the machine. If unclean, sticky or damp, they at once introduce a fortuitous element into machine-composition—a tendency to stop, clog, or to reduce the speed of setting. A machine of this class can handle but one, or at most two sizes of types, and two operatives and a third assistant are required to attend each machine. Without presuming a personal opinion, it would seem that the proportion of the task fulfilled in such systems falls below the efficiencies needful to justify so great an expenditure of mechanical means.

MATRIX-SETTING AND CASTING.

The second great class of machine substitutes for the composition of types by hand is now in order. Here are grouped machines which not only compose the letterpress printing surface, but go farther and produce the letters of which such surface is made up. They not only encroach upon the field of type-composition, but upon that of type-founding as well. There are four varieties of them, which may be touched upon in the order of their evolution, thus:

Machines to impress separate punches, having letters in relief upon their ends, into an impressionable substance, such as papier-maché, and from the matrix thus obtained to cast a stereotype. The difficulties here met with seem well-nigh insuperable, and yet inventors are working to-day along such lines. The failure to precisely align the letters, to secure regularity of drive to the punches, to make-even the lines and to apportion the spacing have ever been primary barriers to successful machine construction.

Soon discovering this, inventors conceived machines for setting up a line of punches formed of movable types, and so forth, previous to impressing them into lead, wood or a softer material. From the assembled stamps a matrix was formed and a stereotype plate was made. Here an advance was noted, in that by using movable elements justification could be done prior to effecting the cast. The difficulties were not less serious than in the preceding machines. The multiplication of stamping dies to equal the frequency with which certain letters were used in a line, and the wear upon the stamps were two obstacles. A machine patented last month by Ole M. Peterson, Chicago, illustrates the last development in this line. More important facts at present engross us.

The third variety of machines proceeds at once from the punch to the matrix, and does away with the former to compose interchangeable matrices, either single or multiple in form, and bearing characters in intaglio, into lines, from which casts are made, corresponding in appearance to a solid line of properly-spaced types.

The single type is the original unit of the printer's art, the fundamental factor with which are wrought all the intricacies of composition. Being handled as units, types have seemed to present a minimum of productive capacity; being handled together, inventors have thought the process a rapid and economic one. Accordingly the idea of raising this unit of a type by making whole words in one piece was employed by type-founders quite early.

It is this enlargement of the unit that forms the foundation of the slug and matrix machines, the only difference being in the mechanisms for accomplishing the results. In the Mergenthaler Linotype, which is the only conspicuous example that we have for comparison, the unit is raised from the type to the line by means of assembled matrices of brass, into which the line is stereotyped. In a lecture before the Balloon Society, London, some years since, John Southward traced this general conception back to 1832, when, in Charles Babbage's book, entitled "Economy of Machinery and Manufactures," a method of stereotyping was thus described:

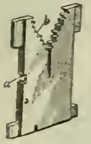


FIG. 14*a*.—Linotype matrix.

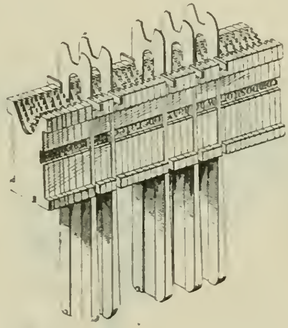


FIG. 14*b*.—Space bands, with assembled matrices.

"Instead of composing the work in movable type, it was set up in movable copper matrices, each matrix being in fact a piece of copper of the same size as the type and having the impression of the latter sunk into its surface instead of projecting in relief."

The changeable matrix is the point of novelty in the Linotype; it is the essence of the invention, for it underlies the possibilities of casting properly-spaced types in lines. Although several machines have been built upon this principle, which seems to have been first exploited by a Mr. Moore, none are now in commercial use excepting the Linotype. The Rogers Typograph, the patents for which were purchased by the company operating the Linotype patents, is out of existence. The Monoline, invented by Mr. Scudder, at one time superintendent of the Linotype shops, is now in interference with a new form of Linotype, proposed by Ottmar Mergenthaler, and hence possesses little of immediate interest. Without prolixity or a needless repetition of details with which all are familiar, some words about the Linotype, its principle and its product, will not be amiss. This machine has reached its commercial stage slowly and with immense effort. It is the result of over twenty years of study, and, if we may believe the words of its British manager, embodies no less than 1,300 patents and applications. Its history would require a volume in itself.

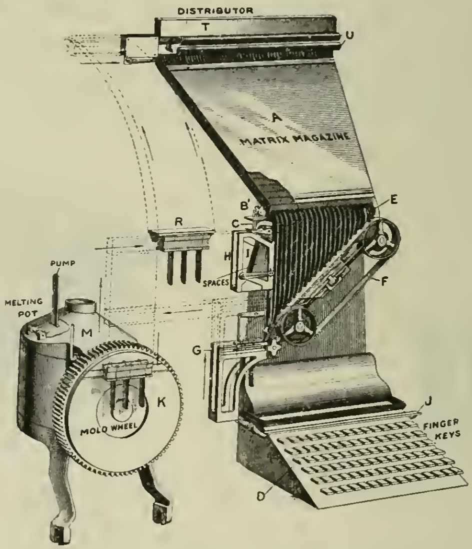


FIG. 14*c*.—Linotype machine, showing main movements.

The Mergenthaler Linotype is a machine in which movable interchangeable matrices are substituted for movable interchangeable types, as used in the type-setting machines. These matrices, of which there are 1,500 in the machine, consist of a flat piece of brass, with a letter or character in intaglio driven into one edge, at *a* (see *Fig. 14a*), and a number of teeth in the upper end, at *b*, which perform the same service as the special nicks given the types for distribution in such machines as have been reviewed. A number of space bands, or wedges (shown with assembled matrices at *Fig. 14b*), are added to these fundamental elements, serving to expand the space between words so as to make the line of matrices justified before the line is cast. By reference to *Fig. 14c*, an admirable plan view published by the Mergenthaler Linotype Company, the process will be made clear. The functions are controlled at a keyboard, the touch upon a key *D* acting upon its escapement *B* to release the corresponding matrix from its magazine *A*. By gravity, this matrix descends through one of the channels *E*, a modified form of guide-plate, upon an inclined travelling belt *F*, and is carried down into an assembly device *G*, where it awaits the arrival of enough of its fellows to complete the line. Between each word, the space bar *J* is actuated, releasing from their reservoir *H* one of the wedges *I*, which drops into line. When the line is filled, it is elevated, carried to the left and lowered to find a place in front of a slot through a mould-wheel *K* (as shown in *Fig. 14d*), against which it is positively held. The wedges are then pushed up as far into the matrices as they will go. The plunger falls into the metal pot, forces the molten type-metal through the mould orifice into the faces of the aligned matrices, and thus effects a cast. The mould-wheel revolves to an upright position for

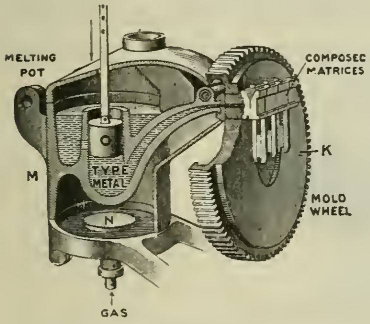


FIG. 14*d*.—Making the cast.

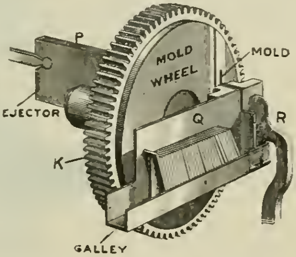


FIG. 14*e*.—Ejecting slugs.

the slot (shown in *Fig. 14c*), and by an ejector the cast (see *Fig. 14f*) is forced out between concealed knives to shave it true. Again reverting to *Fig. 14c,* we see the process of restoring the matrices to their magazines and the space wedges to their storehouse. The cast having been made, and before the mould-wheel revolves, the line is lifted vertically from the mould and shifted to the right until the nicks of the matrices engage with ribs on a bar *R*. The space bands are carried to the right into their reservoir; the matrices rise with the bar on an arm, and pass along the wards of the distributor-arm *T* at the top of the machine. It is not needful to explain this operation; it is elucidated in *Fig. 14g*. Much is claimed for continuity of processes whereby the circulation of matrices and spacers takes place. The machine has a range of ninety different characters, a number about equal to that used in the type-setting machines.

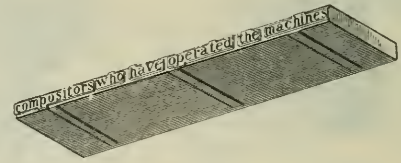

compositors who have operated the machines

FIG. 14*f*.—Linotype slug.

In the chain of operations presented in the Linotype, not a few familiar conceptions are embodied. The machine is practically a digest of everything worthy of adoption that preceded it. The inclined magazine and vertical channels are adapted from the guide-plate; the travelling conveyer is equivalent in function to the travelling belts of one variety of type-setting machines; the distributor is a modification of the principle suggested by Gaubert. It is indeed interesting to see these old-time friends reincarnating so continually before us.

The independently-usable matrix bearing one character is the basic element of the now well-known form of Linotype machine. This is a second type of line-casting machine, the first patents granted to Mr. Mergenthaler being for a machine known as the "band machine," in which a number of type-bars were used, each bearing in relief upon its face the entire assortment of characters used. The characters were selected for use by dropping each bar to the position required to bring each character opposite a fixed point, when the punches were aligned and a papier-maché form produced. It is unnecessary to say that this type of machine was soon abandoned in favor of the present modification.

Ottmar Mergenthaler filed a patent in 1890 for a form of Linotype machine, which is his latest conception, but which involves a distinct reversal of type to his first species of machine. When application for patent was filed by Wilbur F. Scudder, whose machine is known as the Monoline, it came into interference with the Mergenthaler claims, and the case has been carried through different stages until it is now before the Court of Appeals, District of Columbia. Both inventors claim priority for a multiple matrix, which is not a part of the machine, but is independently usable. The primary aim is, of course, to devise a machine in which a smaller number of matrices than the 1,500 now employed can be used to produce the same number of characters, and in which the mechanisms can be reduced from their present complication. Accordingly, Mr. Mergenthaler proposes a matrix, bearing eight characters on its edge or face, driven one above the other. These matrix-bars he suspends upon wires, somewhat after the fashion in the Rogers Typograph, and brings into alignment by checking their presentation of letter at a selected point in their descent. The drawings illustrate broadly the feature of novelty, showing the selected and aligned matrices, *Fig. 15*, and a front view of

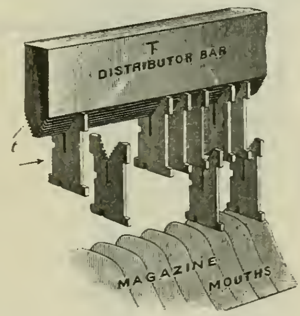


FIG. 14*g*.—Linotype distribution.

the selected characters presented for casting, *Fig. 16.* It is manifest that in such form of machine the element of cost in supplies is increased, as the destruction of one character by the breaking down of its hair-line wall will necessitate throwing away the entire matrix, which is the equivalent of eight characters. To space out this line of assembled matrices, and thus to close the mould, the orifice of which is shown in dotted lines in one of the figures reproduced, the inventor proposes to employ solid spaces, constructed and operated similarly to the matrices, or to utilize wedges, as shown, each wedge having two members, dovetailed together, which slide one upon the other to widen out the line.

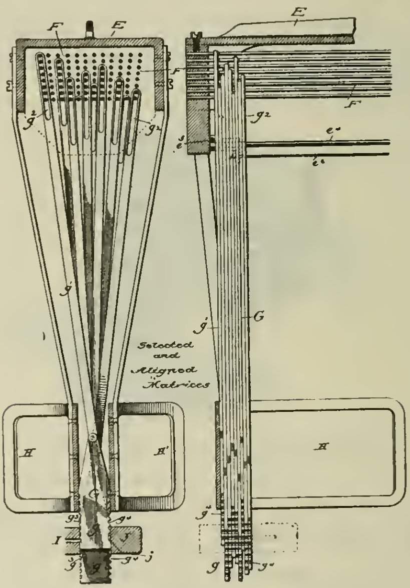


FIG. 15.—Aligned multiple matrices.

Admitting all of the merits of conception residing in the line-casting machines, their ingenuity and patient battle with mechanical difficulties, little appreciated by those unfamiliar with the problem, some critical treatment becomes advisable. Nobody will allege that any principle or the mechanisms interpreting it are more than a compromise with future systems. The Linotype was commercially the first mechanical substitute for hand-setting of type which came into anything like widespread use, being confined largely to newspaper work.

Earlier in the evening it was asserted that the perfectness of a machine depended upon the proportion of the whole task accomplished by it, as well as the excellence of the work it executes. The object in view should be fully attained, but with a minimum expenditure of means. This object in printing is three-fold, viz.: quality, economy and quantity. As to scope, the principle of line-casting includes the functions of type-casting, type-setting, type-distributing and type-justifying, with all the attendant advantages associated therewith. It is accordingly broader than the principles resident in type-setting machinery, and for no other reason has met with adoption. Like every prior machine, the Linotype is limited to setting ninety characters or to have recourse to hand-setting other sorts before casting the line. To handle all the characters represented in a full English font would proportionately complicate an already intricate machine, in which the mechanisms are in direct ratio to the operations; as these are numerous the mechanical means are numerous.

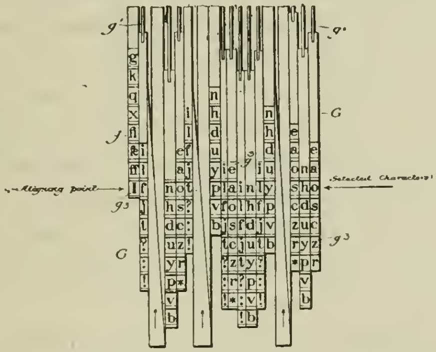


FIG. 16.—Front view of aligned multiple matrices.

THE PRINCIPLE OF LINE-CASTING CONSIDERED.

With line-casting from assembled matrices we have not, as is claimed for these systems, the abolishment of composition, but a substitution of objects to be composed. Instead of aligning types, they assemble matrices, and in manner precisely analogous. The mechanisms proper to type-setting must be approximately duplicated for this operation. The matrices being regarded as permanent units, just as are the foundry-types, they require distributing as the types do. A second chain of mechanisms is needed to perform this, again somewhat analogous to the type-setting machines, which have a distributor. The nature of the system demands the justification of lines before they are cast, as all corrections required must be made by re-casting the line, and that is a factor of loss at the machine, which is a costly investment. This justifying operation calls into life spacers, which again require separate handling, and thus a third group of mechanical means arises. Thus far the operations run parallel to the type-setting machines, besides incorporating a former manual function (justification). This latter is combined with functions generally embodied in two separate machines, so that one machine does all three things. A fourth operation, and that original, characterizes line-casting, and here tribute is levied upon a precise and accurate art, all the established conditions of which must be set aside. This art is type-founding, and here a fourth set of mechanisms is involved, calling for mathematically exact results.

Whether cast singly or in lines, types must be perfectly rectangular in body and uniform in height to admit of printing from, not to speak of the quality of face which also is necessitated. The ancient art of letter-founding, by the experience of centuries, has brought the conservation of these elements to a plane of certitude. The entire progress of typography, artistically considered, has been thus far looked upon as inseparable from single types. The question is pertinent: Can the principle of line-casting contravene the canons of type-founding and equal quality be gotten along an extended printing surface made at one cast? To this those who oppose the slugs reply that a whole legion of evils is raised by casting lines at one operation, that is by the known systems. Those who favor the slugs say that the commercial advantages offset the deterioration in quality of surface. It is significant that such deterioration is admitted. Personally, it is my opinion, acquired during the study of the subject for ten years past, that there are other reasons than caprice or tradition for the type-founder's arbitrary standards. His is perhaps the most exact of the mechanic arts. The type-founder has especially recognized the advantages gained in making single types. A smaller quantity of metal has to be solidified in the mould; the nature of the mechanical problem resident in producing an exact matrix for a single character and a mould for casting the body of the letter is greatly simplified; the surface afforded for contraction in cooling is minimized; the foot of the cast can be made true and solid to the extent needed in standing exactly at right angles with the body; and harder metal can be used, thus adding an increase to the permanency of the height and the wear and tear in printing. The larger body sizes, such as small pica, will naturally enable greater accuracy and speed in casting with single than with unified types. The least departure from exactitude of matrix, alignment of face, or angle of presentation will appear in the resulting cast, and be carried into the printed page.

The proposition is advanced that the four and a half centuries in which typography has been evolving have brought the best conditions to life for the further unfoldment of good printing; also that these conditions, reflecting the experience of thousands of progressive printers in whose hands they have exhibited an excellence of production well-nigh inconceivable, are worthy of consideration, and of preservation if they can be shown to underlie the standards proper to quality. It is an open question, which can be left to the judgment without further discussion.

THE LATEST SYSTEM OF MACHINE SUBSTITUTE.

Most recent in order of time and last in the number of systems before the student of the subject engaging our attention is a novel plan, less complex in mechanical means, though broader in scope than preceding systems, and based upon principles which many think are better adapted to conserve quality and economy. The fundamental conception as well as its subsequent elaboration are due to Tolbert Lanston, of Washington, D. C. The machine is a new species, although here, as elsewhere, a philosophical study will reveal the inductive process which, in the world of invention, is always manifest.

The new principle applied by this inventor may be termed the self-justifying of lines of types by varying spaces between words. The process consists: (1) In ascertaining the length of the proposed line. (2) In finding the space needed to make that line even to the measure. (3) In forming the space types for the line of a width that will absorb the unoccupied space, either by widening each of them if the line is too short or by reducing their width if too long. By the system the spacing is perfectly equalized between words, and the justifying function is made synonymous with casting the space types, thus greatly reducing the mechanical means.

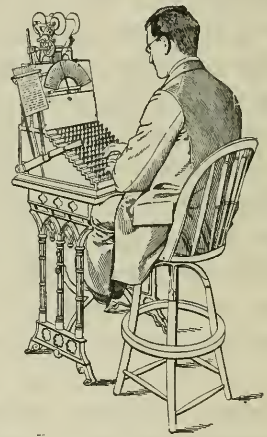


FIG. 17.

The Lanston Monotype system is embodied in a machine for making and setting single types in the order of their use, arranging them in lines which, when the last letter has been delivered, will be properly justified. The machine is in two parts, the first of which is a keyboard, shown in the views *Fig. 17*, at which the operator sits, recording the characters, the body widths of every letter and space, and the addendum needed to justify the lines. The operation is purely manual at this point, and as easy as type-writing provided the rules of type-setting are known. The second part of the machine is automatic (run by belt) and here types, similar in appearance to ordinary types, and of commercial character, are produced set in galleys. The operator at the keyboard produces a continuous strip of paper, like that of which a sectional view is shown, at *Fig. 18*, his work recording the characters in perforated holes instead of printing them as does the typewriter. Each key perforates two holes in a line across the strip. One of these holes records the position of the vertical row to which the key belongs; the other records the position of the horizontal row.

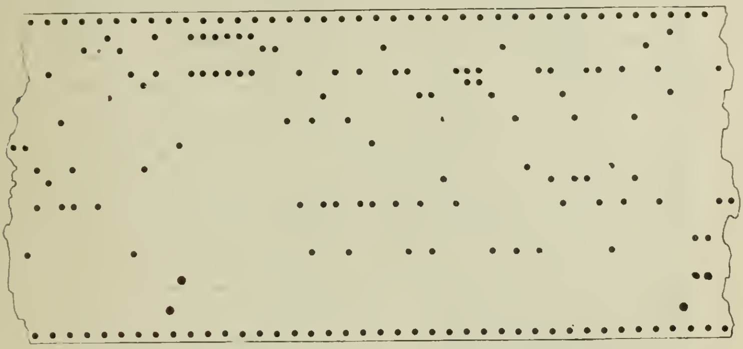
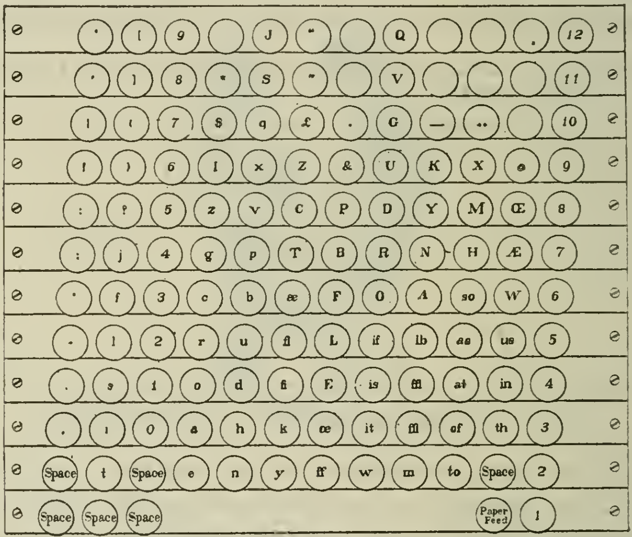


FIG. 18.—Record for composition at Lanston Monotype.

Thus, taking the arrangement of the keyboard, exhibited in *Fig. 19*, the actuation of key representing the upper-case *B* would record holes on the strip showing that it was at the point of intersection of the seventh vertical and seventh horizontal rows that the character was located. The record is thus progressively made, letter after letter, and space after space, the machine meanwhile doing a sum in addition, by the simplest of mechanical means. The end of the line is approached, a bell rings, the operator glances at a space register, which records the number of spaces used in the line, and then by glancing at a scale before him takes cognizance of the space to be added. One second is sufficient to record the addendum on the row of keys at the right, which also perforates holes at the end of the line. All sizes of types from 6-point to 11-point and all commercial measures can be effected at the keyboard without change, save an adjustment which takes less than ten seconds.

The reel of paper is supposed to bear the equivalent of the finished composition, either in long or short "takes," as may be desired. It is taken to the casting machine, placed in position and the power started. As the strip advances by means of the marginal holes which are fed over spurs, the two perforations representing a type are pneumatically caused to affect the travel of a die-case, the arrangement of matrices in which is like that shown in *Fig. 19a*. This die-case carries matrices in the form of small steel cubes, in one end of which is driven an intaglio of the letter, etc.; a solid wall is always afforded to the character; these matrices are arranged in rows, located analogously to the keys on the keyboard, and are carried in a rectangular case, which travels on a compound slide. The cap B which we selected was at the seventh vertical and seventh horizontal rows of the keyboard; it is at the same point in the die-case of the casting machine, see *Fig. 20*. This matrix is accordingly selected by the corresponding or governing perforations, and the die-case caused to travel horizontally on the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] 8 * S V 11
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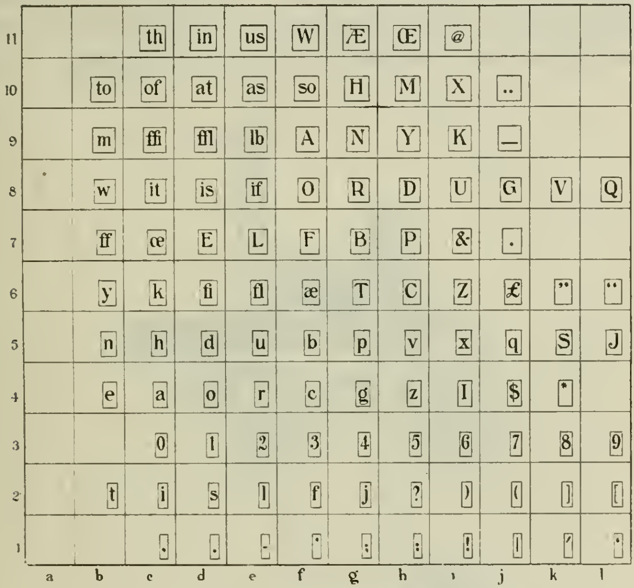
- l 2 r u fl L if lb as us 5
. s 1 o d fi E is ffi at in 4
. 0 a h k œ it ffl of th 3
Space t Space e n y ff w m to Space 2
Space Space Space Paper Feed 1

FIG. 19.—Arrangement of keyboard—Lanston Monotype.

slide—matrix end of the steel cube undermost—so as to locate it directly over a mould, closed on three sides, and with an adjustable blade which opens the exact width needed to make the different widths of type. Being centered over the mould, the matrix is depressed to form a tight joint and the metal is forced from a metal pot through a nozzle into the foot of the mould, filling it and the matrix, and chilling to form the body and face of the type together, the type when cast being on its feet. A jet-forming device in the mould breaks the force of the current, prevents the metal from flowing away from the face, and ensures the proper filling. The jet is removed after the cast is made, the type is ejected and by carriers is conveyed to the line in an ordinary galley, in which the matter automatically advances to receive each line. The features of the machine are its simplicity, its directness and its accuracy. Types are made normal; space types are of justifying width; corrections are made as with hand-set types, the machine producing its own sorts; and lines are made-even to practical perfection.



11			th	in	us	W	Æ	Œ	@			
10		to	of	at	as	so	H	M	X	..		
9		m	ffi	ffl	lb	A	N	Y	K	—		
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7		ff	œ	E	L	F	B	P	&	.		
6		y	k	fi	fl	æ	T	C	Z	£	”	“
5		n	h	d	u	b	p	v	x	q	S	J
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	a	b	c	d	e	f	g	h	i	j	k	l

FIG. 19 *a*.—Arrangement of matrices in die-plate.

There is no alteration in the methods now in vogue for handling foundry-letter after it is in the galley.

After the complimentary award to Mr. Lanston of the highest honor in the power of the Franklin Institute to bestow, and the publication of so admirable a report about the machine, it is unnecessary to treat upon mechanical details. Technically, some concluding words are called for. First, as to chain of operations. This system includes the production of the compositor's raw material on principles modelled after the latest results of type-founding. It has adapted, not revolutionized, principles admittedly exact and scientific. It elides the function of distribution entirely, either of matrices or of types, while embodying all the advantages thereof. It combines the setting of the types with the justification of the lines at one operation and without two series of mechanisms. It employs no gravity, has no travelling conveyers outside of a compound slide with a maximum travel of 3 inches, and involves no restoration of matrices. In a word, it appears that the series of mechanisms have been minimized while the chain

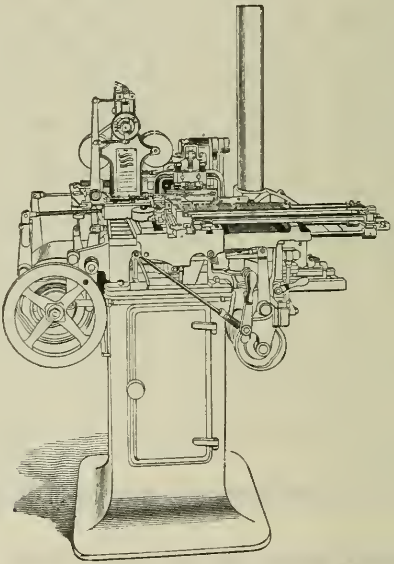


FIG. 20.—Casting machine—Lanston Monotype.

of operations has been lengthened to comprise the varying requirements of composition. No other system has proposed to deal with more than 90 to 100 characters, which is a compro-

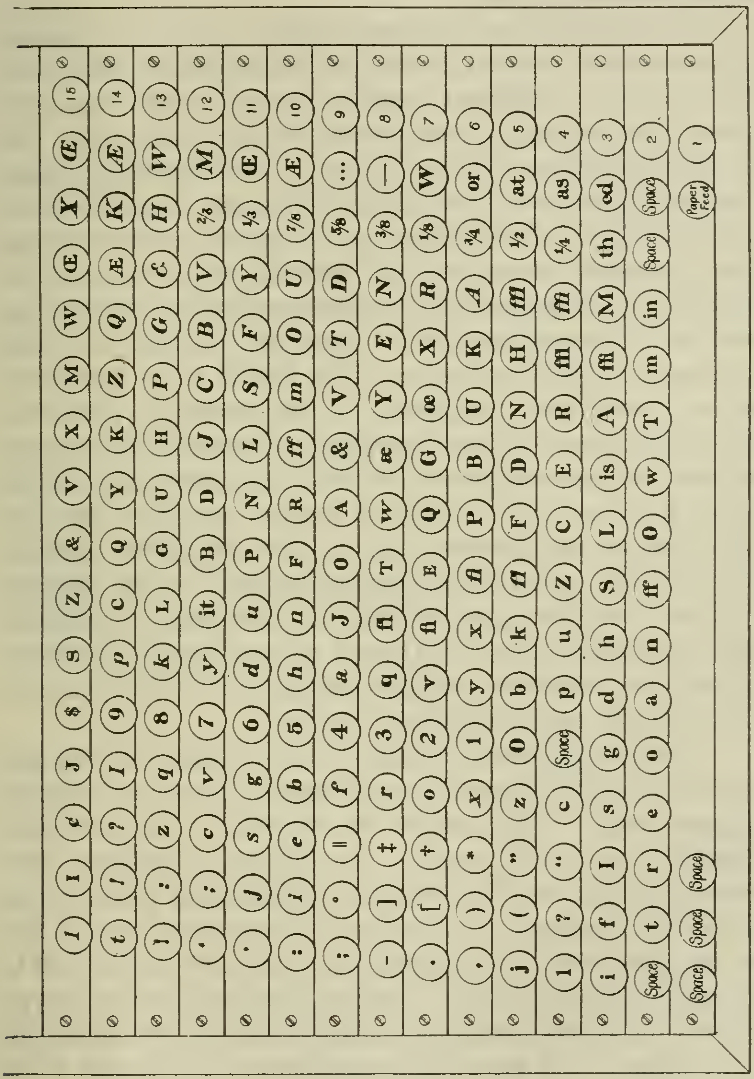


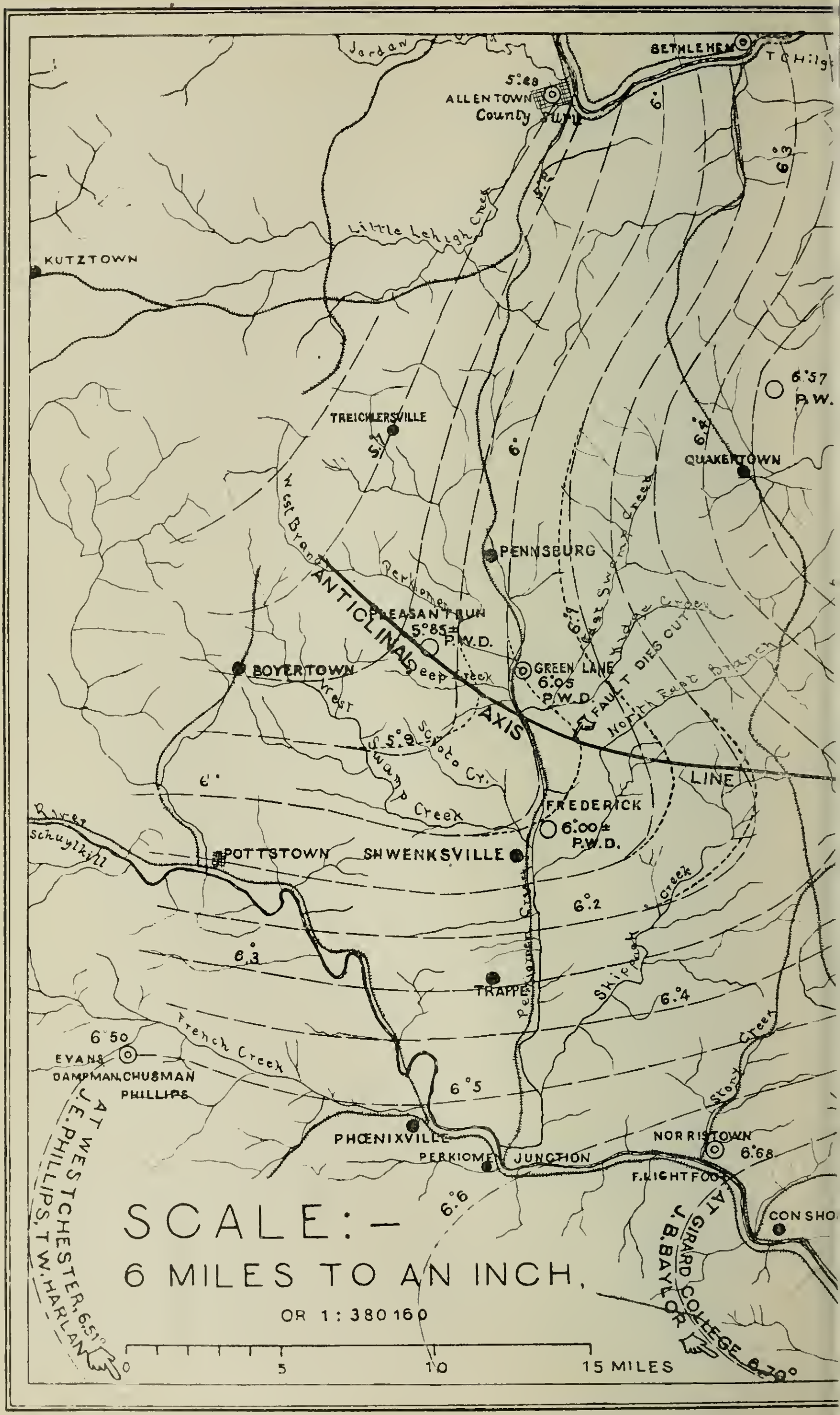
FIG. 21.—Full font keyboard for Lanston Monotype.

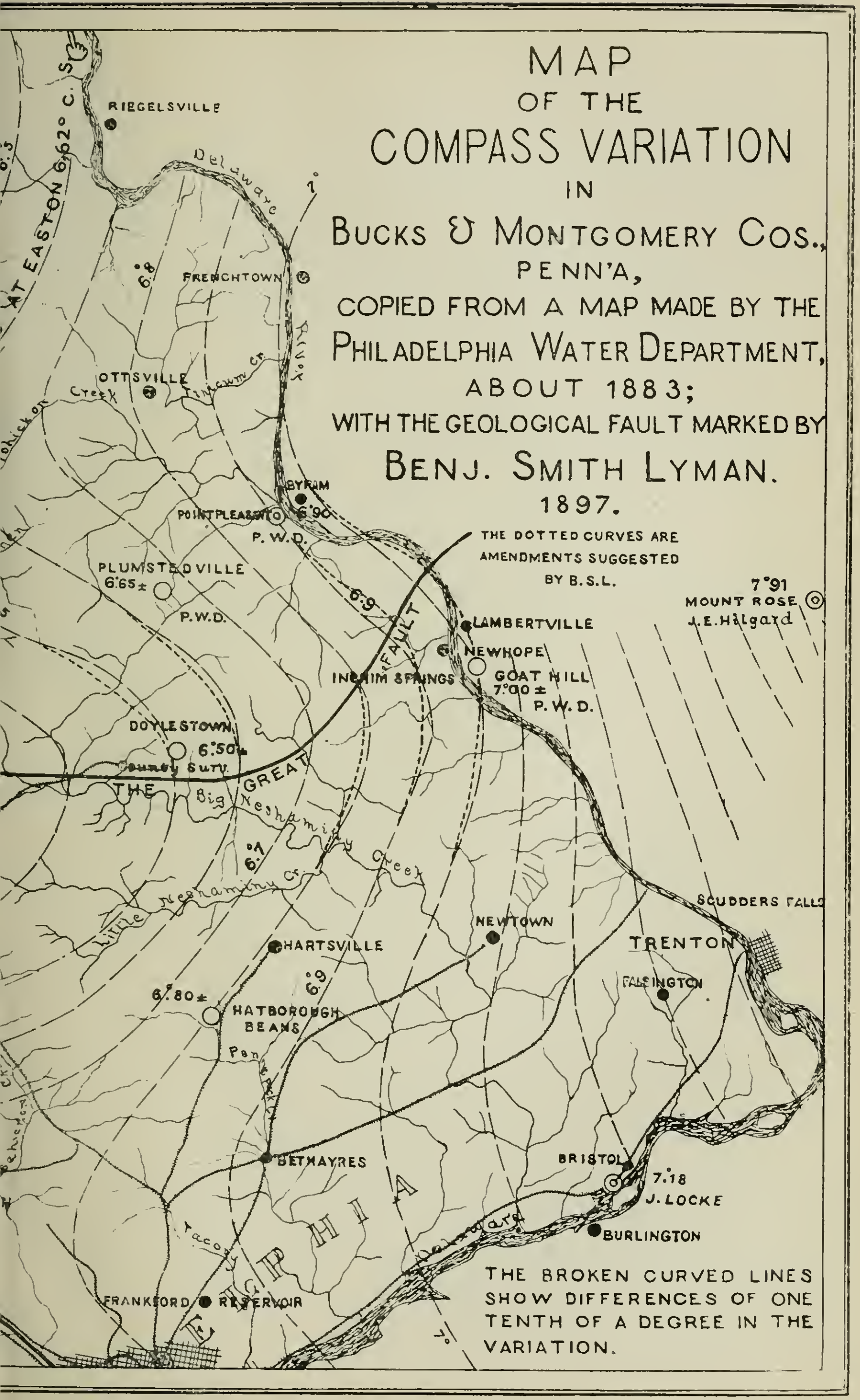
mise with the full English font of 226 letters. The keyboard shown in *Fig. 21* illustrates a range for book-work, which is proposed in the Lanston Monotype machine. As the square die-case may contain any number of characters by merely increasing the rows, the use of fifteen rows, each way, will give 225 characters, with but thirty mechanical movements, and no marked increase in parts.

In all precedent and contemporaneous systems a magazine and devices are required for each set of characters, each character is needed in sufficient quantity to meet possible frequency of use in the line, and spacing means must be dealt with. All are eliminated from the new system. The advantage gained in separating manual from machine functions places each element at the apex of its efficiencies; the fatigue or uncertainties of the operator do not limit the untiring performance of the machine, nor are the possible derangements of the machine fastened upon the shoulders of the operator with whom so large a proportion of the cost resides. The quality of the product is said to parallel the possibilities of the automatic perfecting type-machines used in large foundries. Finished types are now produced by these machines one-third faster than at the steam casting machine, and an eminent founder says that "the face of the type is much sharper, there is more regularity in thickness and body, and more general uniformity" to the product. With the hand-cast types, as picked, 15 per cent. are rejected; with the steam machine-cast types, 5 per cent. are thrown away; but with the automatic machine-cast types the defective casts do not amount to one-eighth of 1 per cent.

In terminating these remarks upon a branch of the mechanic arts too little known, the machine of the future naturally suggests itself. What will be its character? The industrial prophet is an unsafe augur. No one may predicate what potential germs may be even now propagating in the fertile soil of minds inclined to invention. We may not predict. But we may generalize, may assume that what will survive will be the fittest, will give birth to further developed form and type, and that the purely natural processes of the past will hold good in the future. We have illy comprehended the history of invention if we have not learned that a more or less logical sequence of thought lies in every invention. An invention is no special inspiration, it results from the gradual assimilation of

Jour. Frank. Inst., Vol. CXLIV, October, 1897.





MAP
OF THE
COMPASS VARIATION
IN
BUCKS & MONTGOMERY COS.,
PENN'A,
COPIED FROM A MAP MADE BY THE
PHILADELPHIA WATER DEPARTMENT,
ABOUT 1883;
WITH THE GEOLOGICAL FAULT MARKED BY
BENJ. SMITH LYMAN.
1897.

THE DOTTED CURVES ARE AMENDMENTS SUGGESTED BY B.S.L.

THE BROKEN CURVED LINES SHOW DIFFERENCES OF ONE TENTH OF A DEGREE IN THE VARIATION.

means already arrived at. The process is purely an inductive one. The machine of the future resides potential in the machine of the present. Which is the fittest of present systems to give it birth I leave you to determine. One thing is certain. The machine of the future will have for its share of the work the entire task which admits of machine execution, it will make the least demands upon operative skill, and the expenditure of mechanical means will be in inverse not exact ratio to its functions.

Mining and Metallurgical Section.

Inaugural Meeting, held April 28, 1897.

MR. JOHN BIRKINBINE in the chair.

COMPASS VARIATION AFFECTED BY GEOLOGICAL STRUCTURE IN BUCKS AND MONTGOMERY COUNTIES, PA.

BY BENJAMIN SMITH LYMAN.

The purpose of this paper is to call attention to a remarkable correspondence between the strongly bent axis of seemingly very irregular curves of magnetic declination and an independently demonstrated profound fault, dying out into a sharp anticlinal, in the new red region of Bucks and Montgomery Counties. The magnetic curves were mapped some years before the beginning of the recent geological survey, that for the first time fully proved the peculiar structure; but the curves had no influence whatever in the interpretation of the geology, and the correspondence was not perceived until long after the geological map was printed.

The magnetic map was made about the year 1883, by the Water Department of the city of Philadelphia, for use in its excellent topographical survey of the Perkiomen and neighboring valleys under Mr. Rudolph Hering. The map records the results of a number of determinations of the magnetic declination made by the Water Department itself and by the Coast Survey and by other observers, and curves of equal declination were drawn for every tenth of a degree. The curves are so extremely at variance with the simple, nearly straight, lines of earlier less detailed maps, as either to show extreme confidence in the accuracy of the observations, or perhaps even to excuse a suspicion of the possible incorrectness of the curves in some way, especially in view of the acknowledged want of precision of some of the observations, and the absence of any obvious topographical or other occasion for such great irregularity. But the curves are in the main beautifully confirmed and thoroughly vindicated by the underground geology.

The striking feature and dominant peculiarity of the curves is a very strong bend convexly northeastward near New Hope and Lambertville, on the Delaware; but gradually changing towards the west, so that the curves near Shwenksville and Boyertown point still more sharply southeastward. The axis of the bend in the curves is, then, itself greatly bent, nearly to a right angle. The geological survey of the two counties, begun at the end of 1887, has proved beyond a question the existence of an enormous fault, of about 14,000 feet, in the rock beds, almost precisely on the line of the Delaware River end of that magnetic axis, and following the same course past Doylestown, gradually dying out, and west of that town turning northwestward, passing north of Shwenksville, disappearing there as a fault, but continuing as a sharp anticlinal to the border of the New Red and of Montgomery County, 5 miles northeast of Boyertown.

The geological structure of the map of 1893, published by the State Geological Survey, was drawn without the least reference to the magnetic curves, and indeed without any knowledge at that time of the slightest correspondence between them and the geology. The geological map gives the direction and amount of the dip at a couple of thousand points, amounting to a complete demonstration of the structure, and to a full proof of the situation and extent of the fault and of the sharp anticlinal into which the fault runs. The topography also given on the same map shows that there is no one strongly-marked ridge following the course of the axis of the magnetic curves. Indeed there are more decided topographical indications in the way of long, rather high ridges in other directions. Furthermore, the form of the out-cropping rock beds, sedimentary or igneous, does not correspond in any degree with the magnetic curves.

It is perfectly clear, then, that the remarkable magnetic peculiarity of the region must be closely related to the equally remarkable and completely corresponding geological structure; and if either were in need of corroboration, the confirmation given by two such thoroughly independent pieces of work would be of the strongest kind.

Moreover, some light is perhaps thrown upon the obscure subject of terrestrial magnetism. It is true, the nature of the relation between the magnetic and geological phenomena is not so easily determined; but it seems to become certain that the internal structure of the earth's crust has an important influence upon terrestrial magnetism, even if it be not in any degree its first cause. Terrestrial magnetism and its changes have sometimes been considered explainable by solar influences alone, no longer by direct action of the sun as a magnet, but by the sun's heating the atmosphere or the earth's crust. The present phenomena seem, however, to point to more strictly terrestrial processes as the true cause, and to suggest that the solar influence may partly at least be exerted through the attraction of gravitation as well as through heat. The enormous and locally unequal strains produced by the contraction of the earth's crust in cooling would be particularly liable to be affected by the presence of a deep fault or by a sharp anticlinal. Such lines would be places where the crust has yielded and is readier to yield, and consequently where the strain has been to some extent relieved and is less. The recent occurrence of earthquakes along the New Jersey end of this very fault line shows that the resistance there is less, and that the remaining strain must likewise be less. On such a comparatively weak yielding line the rock beds in readjusting themselves, even where there is no violent earthquake, must occasion a certain amount, not only of strain, but of friction and heat that might give rise to electrical currents. A decided magnetic effect, too, has sometimes been observed to accompany earthquakes, and in some cases to precede them. In like manner, the strains and yielding or readjustment that may be occasioned by the attraction of the sun and moon might apparently cause electrical currents; and, in fact, magnetic disturbances have been found to correspond, like tides, with the place of those heavenly bodies. Again, the broken or arched form of the rock beds may permit at least a temporary local variation in the temperature of the crust, as affected by the earth's hot interior, that could occasion electrical earth currents. Terrestrial magnetism seems then to arise not only from the manifold action of the sun's heat upon the air and the earth's crust, but from the internal movements of the crust and from the tidal effect of the sun and moon upon the air, ocean and solid earth.

PHILADELPHIA, APRIL 26, 1897.

POSTSCRIPT.

The discussion that followed the reading of the paper suggests the need of a few further remarks. The question was raised whether deposits of iron ore, some of them as much as 50 miles away, could not have so affected the compass variation at the points determined as to give the magnetic curves the peculiar form on the map. But the power of iron ore to affect the magnetic needle at a distance is apt to be exaggerated, somewhat after the fashion of the ancient oriental tales of the lodestone that drew men's boot-nails, and of the seaside mountain that pulled the bolts out of ships' sides. Deposits of magnetic iron ore, though differing much in magnetic force, seldom directly affect the most delicate magnetic needle at a distance of more than a few hundred feet. If they sometimes appear to have a more distant effect on the needle, our present experience would strongly indicate that it is because the iron ore happens to be at some line of such great structural importance as to give rise to a diversion of electrical earth currents. Furthermore, it is hardly conceivable that just these peculiar Bucks and Montgomery forms of the magnetic curves could have been produced by any known deposits of iron ore or trap, whether near or distant, whether strongly magnetic or weakly so, or could have been occasioned by anything else than the closely corresponding equally irregular geological structure.

The number of points (18) where the magnetic declination was determined is not very great, yet sufficiently so to make it impossible to draw any essentially different curves that would conform to them. Nevertheless, it is obvious that the magnetic curves, while not made essentially different, might with the greatest ease be so slightly changed as to have their axis conform exactly to the course of the fault and anticlinal; and several such proposed amendments have been dotted in upon the map. The close agreement of the strongly bent axis of the curves with the geological line of fault and anticlinal is therefore a surprising confirmation of the correctness of the magnetic observations, and at the same time thoroughly indicative of some causal connection between the two phenomena.

Some of the magnetic irregularities that were instanced during the discussion may be wholly unexplainable with our present knowledge of terrestrial magnetism; but if they be not connected with mere temporary disturbances—magnetic storms—we can now see that they may be due to hidden geological structure, in some cases, perhaps, submarine as well as subterranean. It is evident that it is highly desirable that the magnetic investigation of every portion of the earth should be thoroughly carried out, in order to ascertain more fully the world-wide magnetic laws. Such work is, in particular, one of the most important parts of Arctic and Antarctic exploration, one that must be of practical value to surveyors and navigators of every other region.

MOTOR ROAD VEHICLES.

By Joseph Sachs.

[*Concluded from vol. cxliv, p. 233.*]

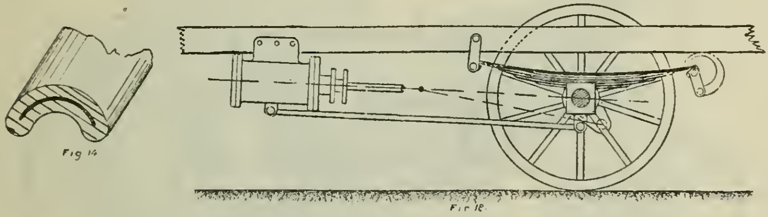
Arrangement of Controlling and Operating Appliances.—The mechanism put in the hands of the operator for controlling the vehicle, as well as certain other parts of the apparatus which need his attention, should be free from any confusing element and require no technical skill for their proper operation and maintenance. Particularly important and desirable is an arrangement of controlling devices, and, in fact, general mechanism, which is fool-proof, and which will not, under any condition demanding quick and rapid action, confuse the operator.

A variety of arrangements of the different controlling levers and other mechanism needed to start, stop or charge the vehicle have been adopted. A separate device controlling each particular action has unquestionably a great deal of simplicity, although perhaps somewhat confusing if the number becomes unreasonable. An arrangement wherein the control of various functions is centered in a single device, which may be given varying movements to produce the necessary results, has probably some advantages.

The general principles above discussed are generally applicable to any form of motor vehicle, but particularly, however, those intended for light service. Following will be a number of specific features in connection with each of the three distinct classes of motor vehicles.

Steam Motor Road Vehicles.—It is unnecessary to speak of the general features of portable steam motive power any more than to say that such motors are easily started and stopped, regulated in speed and reversed. The fuel and water necessary is easily procurable and cheap. Owing to the ease of regulation and control, the gearing and connections between the motor and the driven elements would be exceedingly simple, and, as a whole, such motive power would not be costly.

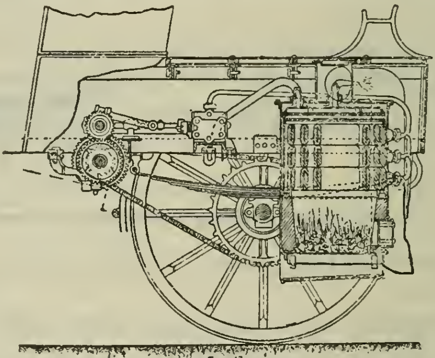
Steam motive power, however, for this purpose, in its ordinarily arranged form, has various disadvantages. Aside from the difficulty of evolving a satisfactory small engine and boiler, the power capacity of such motive power is limited. If the demand exceeds the maximum effort of which the motor is capable, while stalling may not result, yet the effect may be equivalent thereto. It is certainly essential that this type of motor as well as any other should be automatic in its action. Solid fuel is therefore scarcely to be considered, and if oil fuel is to be used, its direct combustion in a gas engine cylinder would produce more efficient if not also other advantageous results. Automatic water feeding to the boiler is essential. Exhaust into the air is also objectionable. Condensing apparatus, which would therefore be essential, adds additional complication. Unless the engine and boiler is entirely automatic, the generation of steam when the engine is inoperative would necessitate blowing off either into the atmosphere or elsewhere with any type of water-carrying boiler. Such boilers also have, however, many other objections, in which the danger element is not the least. In addition to the above, such portable steam motors as would be required would undoubtedly require skilful attendance, and would certainly be somewhat unclean and uncomfortable.



Serpollet boiler tube and direct connected steam engine.

Undoubtedly there are most promising possibilities in the future development of the steam-propelled motor vehicle. Rotary engines, instantaneous generation boilers and suitable automatic motor-controlling mechanism will do much, if practically and commercially operative, to advance the status of the pioneer of motor vehicles. At the present time such motive power would seem to be limited to the heavier type of vehicle.

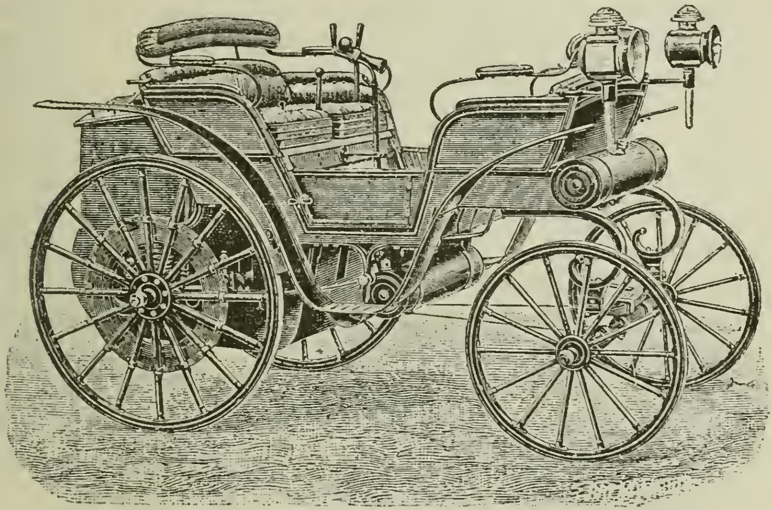
Amongst recent European productions the Serpollet steam carriages are particularly notable, owing to the peculiar instantaneous-generation boiler with which they are fitted. This boiler consists of several coils of very thick flattened water tubes, having a flat opening approximately one-sixteenth of an inch, between the flattened inner sides of the tube. These tubes are dry-heated to a high temperature by a coke fire, and are directly connected to the engine cylinder. In several modifications, however, automatically controlled oil-firing apparatus is used. Steam is instantly generated and superheated as the water is forced into the boiler tubes by means of hand- and power-operated pumps. The engine is regulated by the amount of steam generated, depending upon the quantity of water forced into the tubes. The supply of the latter is therefore controlled by a valve, regulating the starting, stopping, and varying speed and power of the engine, which is usually of from 4 to 5 horsepower. Exhaust steam is superheated and passes off in invisible vapor beneath the vehicle. These vehicles are quite heavy, but can carry fuel for a journey of from 40 to 50 miles. It is notable that actual tests have shown the efficiency of a combined boiler engine to compare favorably with that of fairly large Corliss units. The success of the vehicle, however, de-



Serpollet boiler and driving gear.

pends upon the ability of the boiler to stand the usage to which it is subjected. Steering in these vehicles is accomplished by the short hub pivoted axle method, and the boiler, engine and mechanism are located over the rear drive wheels, which are connected to a drive shaft fitted with balance gears and operated by the engine by means of a chain and sprocket.

American steam-propelled vehicles have not reached any particular degree of perfected development. The late Stephen H. Roper, of Roxbury, Mass., developed several carriages of this type, the last being a 70-pound (including all mechanism) steam bicycle. Mr. Roper lost his life in experimenting with this machine, which could be operated at a speed of nearly a mile a minute, and forms a striking contrast to the massive and heavy European construction.



A German Daimler motor carriage.

Under this classification, vehicles propelled by vapors given off by heated liquid other than water may also be included. Alcohol and naphtha engines have given very excellent results as applied to boat propulsion. It would appear that the latter type of motor might also readily lend itself to the propulsion of road vehicles.

Gas and Vapor Motor Vehicles.—There has probably been more experimentation with and development of gas and vapor motors for the propulsion of road vehicles than of any other type. This fact is probably primarily due to the peculiar self-contained character of such motors, their light weight and the ease of obtaining fuel for their operation and the small bulk and weight of the latter required for comparatively long runs.

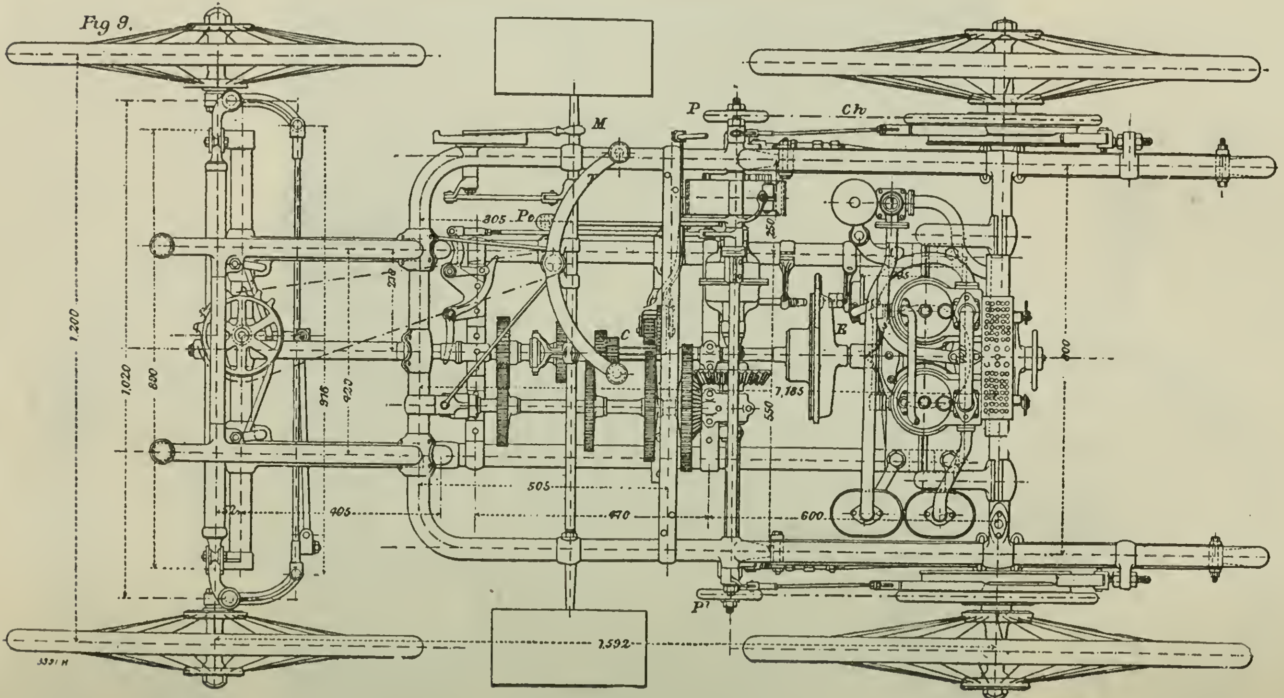
The operation of such engines need scarcely be gone into here. The complete transformation from fuel to power in the engine cylinder, with scarcely any preparation and delay, is a particularly important point in their favor. Both single and Otto-cycle engines have been applied. The latter, however, seem to possess many advantages for this particular purpose. Fly-wheels are essential with either type, and air or water cylinder cooling jackets are essential, although wasteful. Although many attempts have been made to produce the rotary gas engine, nothing feasible has as yet made its appearance in this direction. The impulsive exertion of effort in such engines has led to the adoption of multi-cylinder arrangements, giving more or less balanced operation. For motor vehicle purposes, compressed gas might be carried, but some easily vaporized product of petroleum, such as gasoline, benzine or ordinary kerosene has been generally used. Light oils, giving off inflammable vapors at ordinary temperatures, may be used, but the usual method has been, however, to accomplish this result by the use of slightly heavier oils, and the application of some heat, or by the use of atomizing or spraying vaporizers.

Gas engines are not self-starting, which probably is one of their greatest disadvantages, necessitating the use of separate starting devices. The lack of speed varying and reversing ability in the present forms of engines necessitates the use of gearing for this purpose. The stalling of such engines by overloading them makes the adoption of excess motor capacity advisable.

Automatic flexibility of the power capacity, which is so important a factor in this particular field of application, is entirely absent. Automatically operated gear changing or clutch devices might be considered.

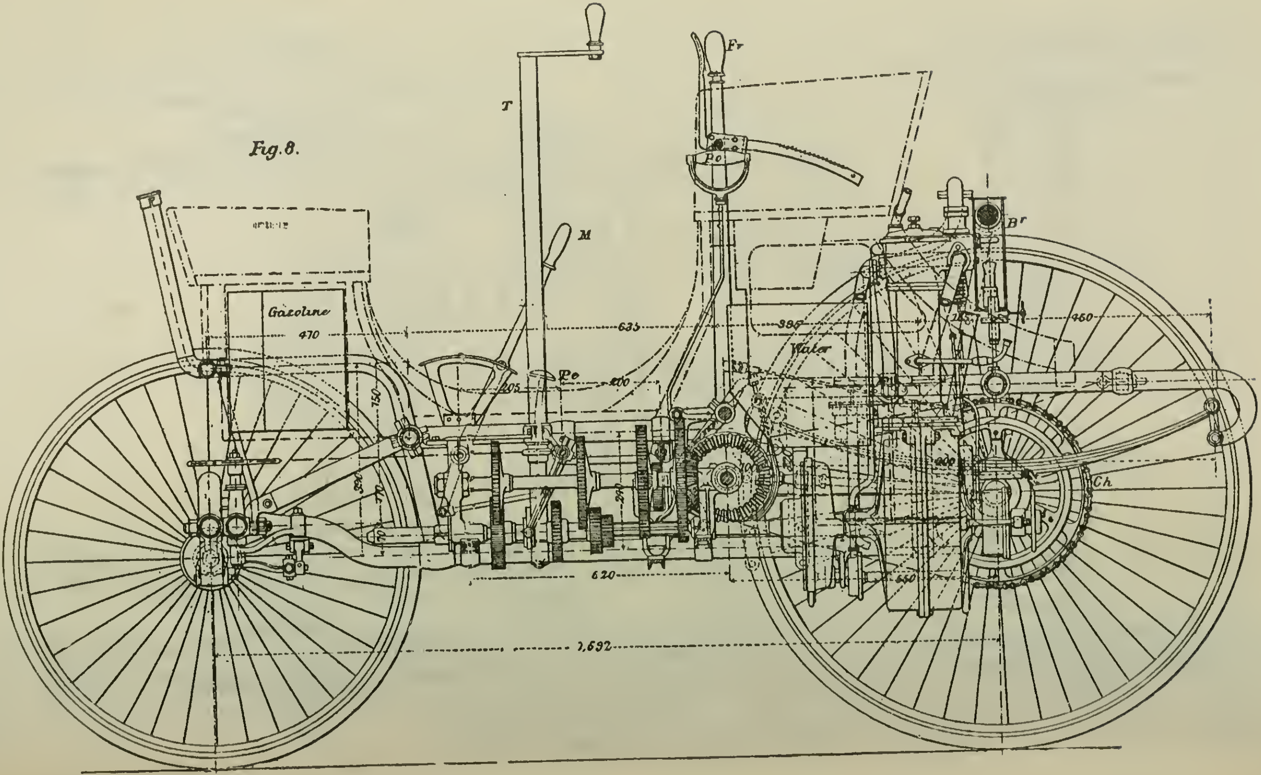
Probably most prominent amongst the various European

Fig 9.



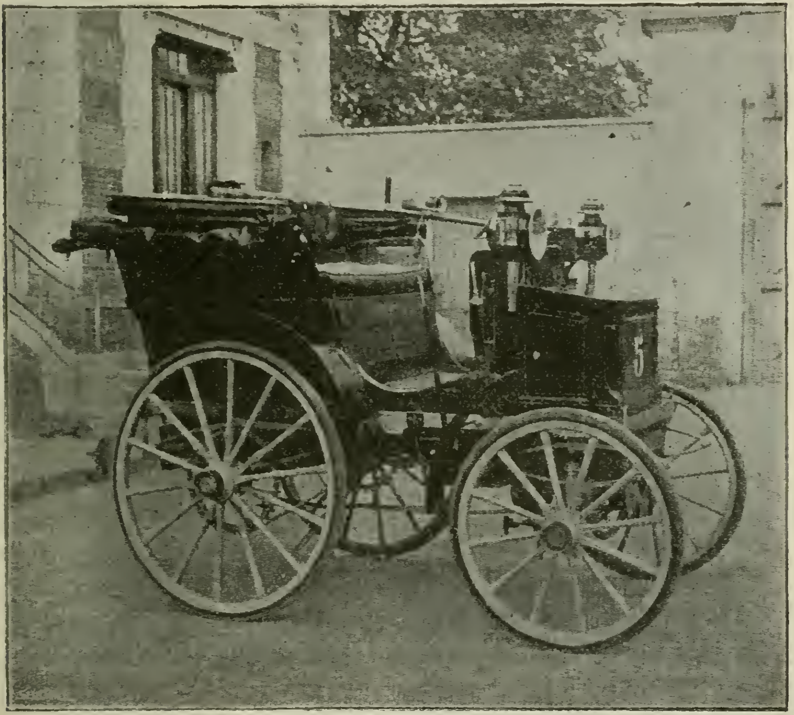
Plan of Peugeot vapor motor vehicle.

Fig. 8.



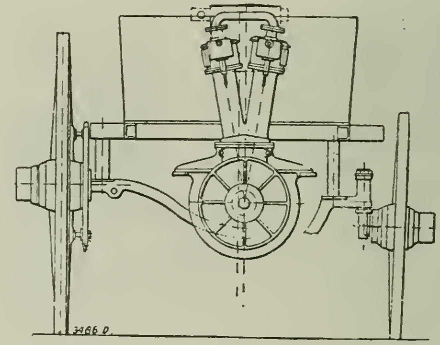
Longitudinal section of Peugeot vehicle.

vapor motor vehicles are those using Daimler gasoline engines. Daimler motor vehicles are also being developed in this country. The Peugeot and Panhard and Levassor vehicles are prominent amongst the European productions. Both of these vehicles employ the Daimler motor, which is of the Otto-cycle type, having two water-jacketed cylinders and incandescent tube to ignite the gas mixture. Some heat is used to vaporize the gasoline in a special carburetting apparatus attached to the engine cylinder. The mechanical arrangement and gearing adopted in both vehicles is very similar in general design. The Peugeot carriages employ a motor of about 4 horse-power, which, with the necessary gearing, is vertically placed over the rear driving wheels. The motor is connected to the rear drivers by means of a variable speed gear, of the movable



A Peugeot motor vehicle.

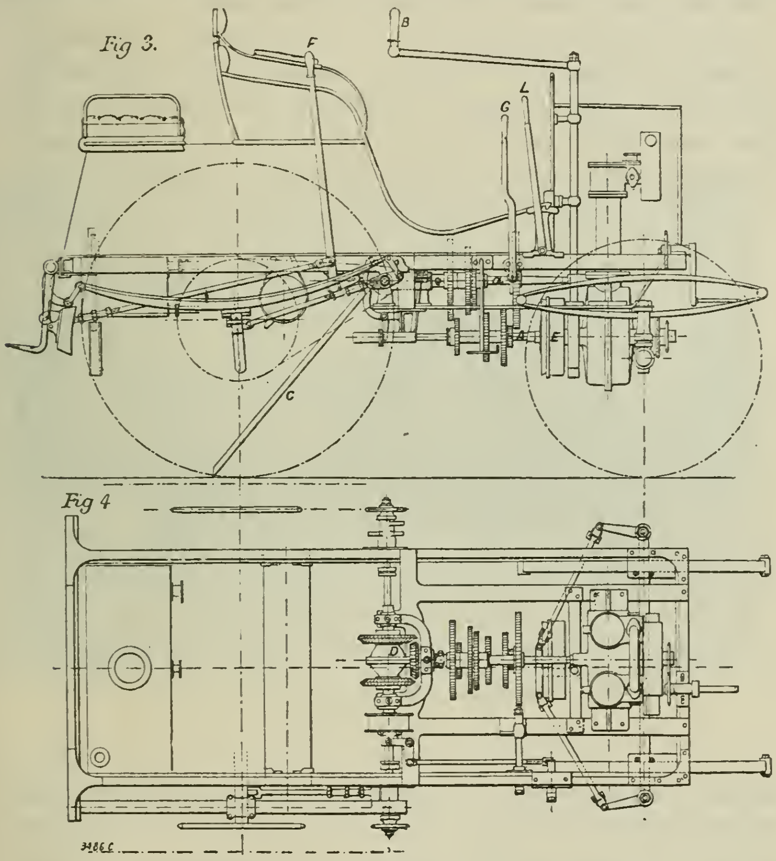
sleeve and single power clutch type. This variable speed gear is connected to a traverse drive shaft, which is fitted with a balance gear and brake pulley, and connected at each end by sprocket chains to the driving wheels, which rotate upon the fixed axle. Tangent spoked metallic wheels are used, with pneumatic tires, and the steering wheels are operated on short hub pivoted axles. Central pivoting of the axle-tree is also adopted. The controlling devices for operating the carriage consist of a lever for shifting the sliding gears on the main shaft, a foot pedal to release the main power clutch, a brake lever, a reversing lever connected to the separate reversing gears, and a steering shaft and cross-bar connected with the short steering axles. The main clutch is always first released before any change in the position of the sliding variable speed gears is made, the engine having previously been started with the gears free. Four speeds, varying from 4 to 14 miles an hour, can be obtained, but only one reversing speed is possible. The steel tubular frame truck construction is adopted for the lower vehicle frame, which is fitted with the necessary mechanism.



Steering gear and engine of Panhard & Levassor carriage.

In the Panhard and Levassor construction, while the same general gearing is used, the location of the motor and mechanism is reversed, being placed over the steering wheels. The complete vehicle is, however, of much heavier construction than the one previously described, the frame being built together of wood and steel, mounted, in some instances, on wood steel-tired wheels.

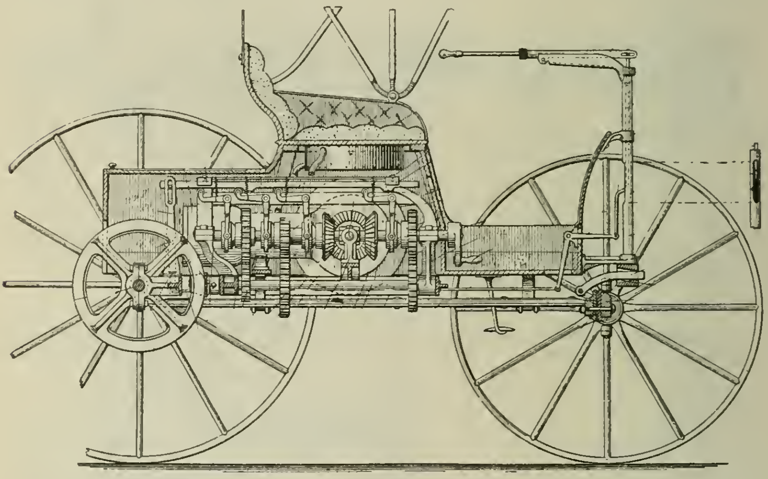
Amongst American gas motor vehicles the Duryea motor carriage has attained particular prominence. The motor used is of the two-cylinder Otto-cycle type, water-jacketed and using gasoline fuel. This motor has a capacity of about 5 horse-power. Separate clutch-controlled gears or pulleys are adopted for variable speed purposes. A single horizontally-placed controlling lever is used for both steering and the operation of this variable speed gearing. The lever extends from a vertically-placed rod in front of the seat. A vertical



Panhard & Levassor Daimler gasoline motor carriage.

movement of the lever controls the operation of the various clutches, while a horizontal movement is transmitted to the steering gear, which is of the short pivoted axle type, with the line of the pivots striking the wheel base contact. A foot-operated brake arrangement is used. The driving wheels are fitted to a revolving centrally-split axle, the two halves of which are connected to a balance driving gear.

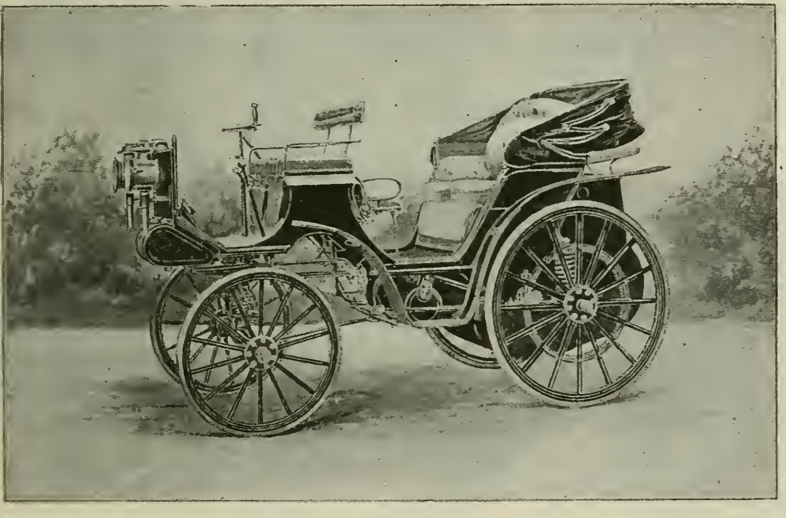
Notwithstanding the many attractive features of gas motor-propelled vehicles, they are beset with many objectionable features, in which the lack of flexibility and starting, variable speed and reversing ability in the motor are pre-eminent. Vibration, noise, odor and deposits from the engine exhaust are also features which it is difficult to entirely eliminate from this type of vehicle. Mechanical appearance and the necessity for more or less skilled attention is also notable. Perhaps another objectionable element is due to the storing of large quantities of oil, which would be necessary where numerous vehicles of this type were operated from some particular point. Probably, however, the generally adopted oil for this purpose will have a safe flashing test.



Section of Duryea early gasoline vehicle.

Great improvements are certainly to be expected in the direction of such vehicles. The production of a gas motor capable of operation at varying speeds and self-starting in either direction, added to the already great advantage resulting from the readily procurable and cheap character of the fuel, will undoubtedly give this type of vehicle a prominent position for many purposes. In their present condition, however, they are still open to much criticism, and their present application is undoubtedly limited.

Electric Motor Vehicles.—It would be impossible to find a more ideal means of transforming energy than the electric motor. The appreciation of this fact is certainly illustrated by its amazingly successful displacement of other forms of motive power. For this particular application, however, we cannot only consider the motor, but must also primarily have some portable means of electrical energy supply. At the present time the storage battery has been almost solely depended upon for such purposes.



A Daimler motor victoria.

Considering the motor apart from the method of current supply, there can be no doubt regarding its absolute superiority over all other present motors available for road vehicle propulsion. Rotary motion, compact construction, light weight and efficient operation are all realized. Starting, stopping, reversal and speed variation are easily effected by means of exceedingly simple noiseless and positive switching appliances. The power capacity, with unlimited current supply, is only limited by the heating of the conductors. While all these features give the motor itself a most ideal position, electric motor-propelled vehicles, as a whole, are somewhat hampered, owing to the present necessity of using storage batteries as a current-supplying medium.

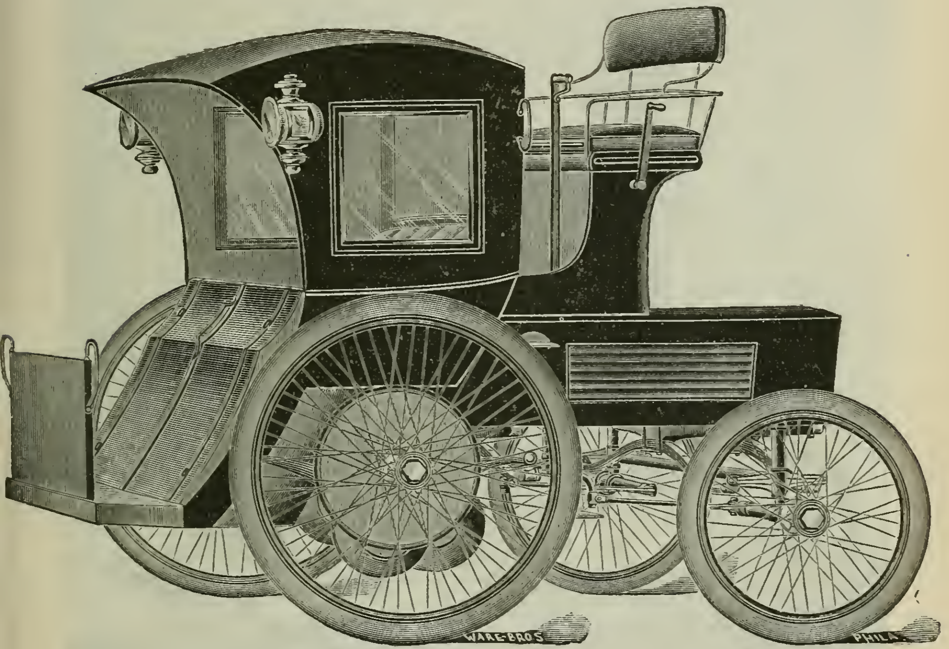
To produce economical results, commercial lead storage batteries must be normally charged and discharged at a point below their maximum capacity. A discharge above the normal usually decreases the life and capacity of the cell, with a certain fixed charge. Although storage batteries for this purpose are specially constructed with a view to give a large discharge rate, with minimum weight and depreciation, yet the battery element of an electric motor-propelled vehicle, even with a comparatively limited traveling capacity, involves a dead weight of almost one-half of the weight of the entire vehicle, which must be hauled about with a constant wasted expenditure of energy. Constant jolting over rough roads is apt to cause some disintegration of the battery element, and by no means the least difficulty, due to the excessive weight of the storage batteries, is its inability to carry long charges and the consequent limitation to a short traveling capacity and only where the proper charging facilities are available.

Electric motor vehicles, however, have so many superior qualities that they give promise of most excellent possibilities even in their present state. Electrically-propelled vehicles seem to have attained particular prominence in this country, and several very excellent constructions have appeared within recent years.

Amongst the recent developments in this direction, the operation of an electric carriage service in New York City is particularly noteworthy. This service includes twelve electrically-propelled hansom cabs, which, in general construction of propelling apparatus and operation, are a type of the well-known "electrobat" vehicles, devised by Messrs. Morris &

Salom, recently investigated by the Committee on Science and the Arts of this Institute, and awarded the John Scott Legacy Premium and Medal. Full details of this vehicle have been presented to the Institute in a paper by Mr. Salom, which was published in the *Journal.**

Various electric motor vehicles, including the hansom cabs, broughams, delivery wagons, etc., have been constructed by Messrs. Morris & Salom. The hansom cab, as used in New York City, is a four-wheeled affair, weighing, complete, about 2,000 pounds. The fore body resembles the ordinary hansom cab lines, but extending rearwardly therefrom is a battery box body. Four wheels of the metallic tangent-spoked type with heavy pneumatic tires are used. Each set of wheels is independent and is separately attached to the body, which is supported on the axles through compound flat springs. As with the earlier vehicle, rear steering and



Electric hansom of the New York City electric cab service.

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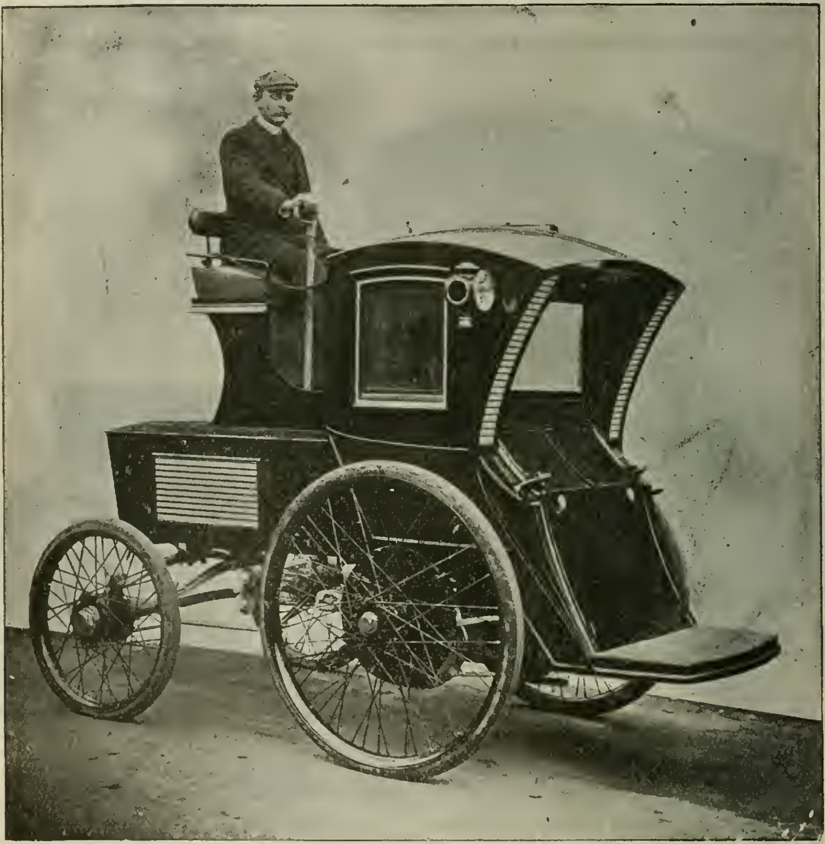
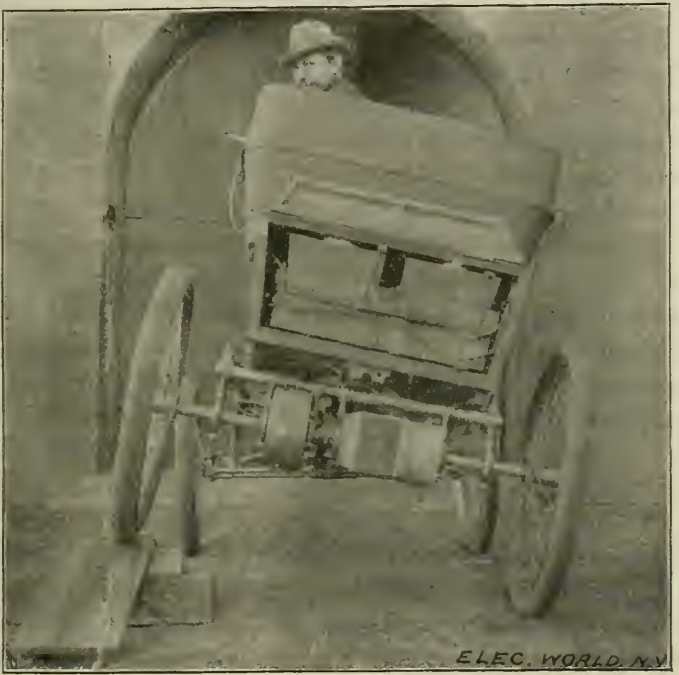
*See *Jour. Frank. Inst.*, **141**, 278.

front driving wheels are used. Each driving wheel rotates on roller bearings on the ends of the fixed axle, and each wheel is separately geared to a single 1½ horse-power electric motor through a single reduction internal spur gear and pinion. The steering wheels are hub-pivoted to the ends of the fixed rear axle.



Morris & Salom electric brougham.

Four trays, of eleven 100 ampère hour "chloride" cells each, making a total of forty-four cells, form the battery equipment. These are placed into the box body through the rear door and connections are automatically made. The batteries and motors are controlled by a single series parallel cylindrical-controller located under the driver's seat and having an upwardly projecting handle at the side of the seat. Three speeds forward and one reverse speed are obtainable by turning the control cylinder to either side of its normal position. At the first speed, from 4 to 5 miles per hour, the batteries discharge at about 16 ampères; at the second, from 7 to 9 miles, the discharge current reaches 21 ampères, and at the third speed, of about 15 miles per hour, 34 ampères. With the lowest speed, the vehicles have a traveling capacity of from 3c to 35 miles, and at the highest, only about 15 miles.



Columbia electric carriage under test, showing battery and motor.

The rear steering wheels are hub-pivoted on the ends of the fixed rear axle and are turned in parallel planes by the spade-handled operating lever in front of the driver's seat, which is moved forward or back to steer the vehicle to either side. A foot-operated brake-lever, close to the steering lever, connects with rubber-roller brake shoes acting on each of the drive-wheel tires.

The Riker electric motor carriages embody many excellent structural features. One of the early Riker vehicles weighs about 1,800 pounds, and has a seating capacity for four persons. The entire upper body rests on a tubular steel frame or truck, fitted with all the propelling mechanism, excepting the battery, which is placed directly under the seats in the upper body. Two 180-pound 3-foot horse-power Riker motors are each separately geared to spur wheels attached to the spokes of the rear driving wheels. Pneumatic-tired steel wire wheels are used, rotating on ball bearings. Current is supplied by thirty-two 100-ampère-hour chloride accumulator cells, weighing 800 pounds, with a capacity sufficient for a four-hours' run at 10 miles per hour over ordinary level roads.

Speeds either way, varying from about 5 to 27 miles per hour, are obtained by the operation of a battery-controlling switch connected to a hand-wheel on the side of the front seat. The front steering wheels are supported on short pivoted axles connected by suitable rods to a horizontally pivoted lever, which can be locked in any position by a slight downward pressure. A band brake on each motor shaft is operated by a foot-brake in front of the operator.

A very elegant electric motor carriage has recently been perfected by the Pope Manufacturing Company, and is named after the well-known bicycles made by the same concern, the "Columbia" electric carriage. In general appearance this vehicle takes the form of a modified phaeton, with highly finished black enamel box body and folding hood, accommodating two persons. This body is supported on an entirely separate tubular steel truck or lower frame, resting on three traversely placed flat compound springs. The complete vehicle weighs about 1,900 pounds. The frame is fitted with the motor gearing and steering appliances, while the storage batteries are placed in the rearwardly extended box body, which has a door at its free end, through which they are handled.

Ball-bearings and pivots have been adopted throughout.

Tangent-spoked metallic pneumatic-tired wheels are used. The front steering wheels are 32 and the rear driving wheels are 36 inches in diameter. The wheel track measures 54 inches, and the distance between front and rear wheel bases 6 feet.

The driving wheels are fitted to the ends of the revolving centrally-split rear axle, which is hung in four ball-bearings from the frame. A balance gear connects the split axle at the junction, the driven member of which is geared through an intermediate gear member to the pinion on the hollow motor armature shaft, which is placed concentrically around the revolving axle, so that the motor is at the side of the balance gear. Special care has been exercised in the construction of the motor, which is of the ironclad multipolar type, with a sectional series field. It has a normal capacity of 2 horsepower, weighs only 120 pounds, and will readily stand an overload of 100 per cent. for some time.

Forty-four "chloride" cells, arranged in four sets of eleven each, comprise the battery equipment. These occupy two sliding boxes, which can easily be placed in or taken out of the battery box. They have a capacity of 70 ampère hours, at a discharge rate of 25 ampères, and weigh, complete, 850 pounds. At 12¼ miles per hour this battery equipment will give a traveling capacity of 30 miles.

Individual operating mechanism is used to control each function. The steering handle is placed centrally in front of the seat and resembles an ordinary car-brake handle. Its movement to the right or left is suitably trasmitted to the short pivoted axle steering gear and wheels, the latter being arranged to move at different angles. A foot-brake lever in front of the seat is connected by a rod to a peculiar double-acting brake band engaging with the outer shell of the balance gear on the drive shaft. The control of the motors and batteries is accomplished by means of a cylindrical control cylinder for effecting 4 speeds by arranging the batteries and motor fields in different series parallel combinations. These speeds vary from 3 to nearly 15 miles per hour. A separate switch is provided for reversing purposes. This switch suitably connects the armature terminals, and is operated by a foot-push and arranged so that it can only be changed when the speed cylinder is in its normal position. Interlocking mechanism is used to prevent its operation at any other point.

It has been particularly desired to make the mechanism of this vehicle automatic in its action and proof against careless handling. An unique device for this purpose consists of an automatic wattmeter-controlled charging and discharging switch. When charging the batteries they may be left in the vehicle, it being simply necessary to insert the plugs of the charging cable into suitable receptacles, which are so arranged that no mistake can be made. The batteries have some resistance in series for charging purposes, so that the cable may be directly connected to any direct current 110 volt circuit. When the maximum charge has been reached, the recording wattmeter automatically energizes the operating magnet of an electro-magnetic switch, which is then opened. The light and non-mechanical appearance of the complete vehicle are notable features.

It is probably unnecessary to dwell upon the various advantages of electrically-propelled road vehicles. Noise, odor, mechanical appearance and other objectionable features are absent. Cleanliness and simplicity and safety of operation are attained to a point far in advance of vehicles otherwise propelled, and a variety of peculiar controlling and operating methods are possible. One or two motors can be used with equal facility. In the latter case, it is possible to control the motors in steering to give the variation in rotation of the inner and outer wheels, although practice has shown that with such motors this arrangement is not essential. Electric braking, either by means of electrically-operated mechanical brakes directly supplied with current from the battery, or dynamic operation of the motor as a dynamo, acting either through a resistance or such magnetic brake device, would be productive of results impossible with other methods. It is also particularly noteworthy that by a suitable arrangement of automatic devices the entire control and maintenance and operation of the vehicle can be made almost entirely automatic, guarding against carelessness or excitability on the part of the operator. With no other motive power and auxiliary appliances can this feature be as satisfactorily and efficiently covered.

If it were possible to substitute some other portable current-supplying medium in place of the storage battery, which would be free from the objectionable weight of the latter, the electrically-propelled vehicle would undoubtedly stand without a peer. A lighter storage of electrical energy, the transformation of heat directly to electricity, or its production by some direct chemical means, is to be hoped for in the future. At the present time it would appear that the storage methods in general use are the sole means available for the solution of the electric-motor vehicle problem. The electric motor is an ideal method of applying energy for propulsion. Why not use a portable self-contained prime mover to generate the needed energy? A gas or vapor motor is a most excellent form of portable motor, the main difficulty existing in its application. Why not combine the two? Certainly the results possible are most promising. Quite true that additional mechanism is essential, but certainly the combination of a gas engine, directly connected to a high-speed dynamo, which, in turn, supplies the motors, cannot be either heavier than the storage supply arrangement or more complicated than the direct gas-motor method. The writer has evolved some new methods in this direction. The objections to the gas motor, in regard to lack of flexibility, starting, etc., have been overcome by peculiar methods of operation. It is reasonable to expect that such a method will not only have all the advantages of the electric vehicle, but also be cheaper to build and operate.

In conclusion, it is entirely unnecessary to bring to your attention the various advantages due to this coming change in the propulsion of at least a large per cent. of road conveyances. Beyond all doubt these are sufficiently ample to rapidly bring about the substitution when the perfected mechanically-propelled road vehicle appears.

STELLAR DYNAMICS.

BY LUIGI D'AURIA,
Member of the Institute.

This most stupendous of astronomical problems, which has defied the efforts of astronomers and physicists, and before which the law of universal attraction seems powerless, can be shown to find an easy solution in the inter-stellar ether, provided the latter is assumed to be ponderable. This fact was proved for the first time by the writer in a paper read before the American Philosophical Society of Philadelphia, May 13, 1897, under the above title, and he now proposes to give his problem a more detailed and exhaustive treatment.

Let us imagine the ether to spread out from the center of the universe spherically to any distance beyond the remotest star, and assume ether to be ponderable. Denote by R and D, respectively, the mean radius and mean density of the earth; by g, the mean gravitative acceleration at the earth's surface; by σ, the density of the ether; by x, the distance of a material body from the center of the universe, and by φ, the acceleration suffered by such body at such distance. Then we can write the following proportion:

$$\frac{\frac{4}{3}\pi R^3 D}{R^2} : g = \frac{\frac{4}{3}\pi x^3 \sigma}{x^2} : \varphi,$$

from which we get

$$\varphi = g\frac{\sigma x}{D R} \tag{1}$$

Considering the center of the universe as origin, an elementary fall of the body towards such center will have to be designated by $-dx$, and we get, from the well-known equations of dynamics,

$$-\int \varphi\, d x = \int u\, d u = \frac{u^2}{2},$$

or

$$u^2 = -2\,g\,\frac{\sigma}{D\,R}\int x\,d\,x,$$

in which u represents the velocity acquired by the body in falling from its original distance ρ, to the distance x, towards the center of the universe. Integrating between the limits ρ and x, we get

$$u = \sqrt{\frac{g}{R}\,\frac{\sigma}{D}\,(\rho^2 - x^2)}; \tag{2}$$

and when the body passes the center, it will have for its maximum velocity

$$v = \rho\sqrt{\frac{g\,\sigma}{R\,D}}. \tag{3}$$

Of course, it is understood that the body in question will oscillate about the center of the universe continually if undisturbed, and its amplitude of oscillation is $2\,\rho$. The period of its oscillation is found by means of the following equation,

$$t = 2\int_0^{\rho}\frac{d\,x}{u},$$

in which, substituting the value of u given by equation (2), and integrating between the limits, we get simply

$$t = \pi\sqrt{\frac{R\,D}{g\,\sigma}}, \tag{4}$$

which expression being independent of the amplitude of oscillation, shows that all bodies within the ethereal sphere would perform their oscillations with the same period about its center.

If the oscillating body is considered moving upon an extremely elongated ellipse, its period of revolution would be expressed by $T = 2\,t$, or

$$T = 2\,\pi\sqrt{\frac{R\,D}{g\,\sigma}}. \tag{5}$$

If a body within the ethereal sphere be subjected to a tangential impulse which would cause it to revolve around the center of such sphere in a circular orbit of any radius such body would have to satisfy the following equation, viz.:

$$\frac{v^2}{\rho} = \varphi = g\,\frac{\sigma}{D}\,\frac{\rho}{R},$$

from which we get

$$v = \rho\sqrt{\frac{g\,\sigma}{R\,D}}.$$

Now the period of revolution of such body is,

$$T = \frac{2\,\pi\,\rho}{v} = 2\,\pi\sqrt{\frac{R\,D}{g\,\sigma}},$$

which is identical with (5), and would seem to indicate that the period of revolution of a body revolving around the center of the ethereal sphere is the same whether such body moves in an elliptical or circular orbit, independently of the dimensions of such orbits.

If the body moves on an elliptical orbit whose semidiameters are a and b, then denoting by x, y, the coördinates of the point occupied by the body at any time, its component velocities, parallel to a and b respectively, will be

$$\sqrt{\frac{g\,\sigma}{R\,D}\,(a^2 - x^2)} \text{ and } \sqrt{\frac{g\,\sigma}{R\,D}\,(b^2 - y^2)};$$

and if we denote by u the absolute velocity of the body in its orbit we must have

$$u^2 = \frac{g\,\sigma}{R\,D}\,(a^2 - x^2) + \frac{g\,\sigma}{R\,D}\,(b^2 - y^2),$$

or

$$u = \sqrt{\frac{g\,\sigma}{R\,D}\,(a^2 + b^2 - z^2)}, \tag{6}$$

in which z represents the distance of the body from the center of the ethereal sphere.

In order now to test the sufficiency of the ether in producing the proper motion of stars, we take for the density of the ether the value given by Maxwell, which is

$$\sigma = 5.32 \times 10^{-19}\, d, \tag{7}$$

d being the density of atmospheric air. If we express *d* in terms of the mean density of the earth, we get approximately

$$d = \frac{D}{4234},$$

and consequently we find

$$\frac{D}{\sigma} = \frac{4234 \times 10^{19}}{5.32}$$

With $R = 20{,}880{,}000$ feet, and $g = 32{\cdot}2$ feet, we get approximately

$$\frac{D\,R}{\sigma\,g} = 517924 \times 10^{22}.$$

and

$$\sqrt{\frac{D\,R}{\sigma\,g}} = 7.2 \times 10^{13}.$$

Substituting this value in (5) we get for our constant period of revolution

$$T = 45.24 \times 10^{13} \text{ seconds},$$

which amounts to a little over *fourteen million years.*

[Maxwell Hall, an astronomer in Jamaica, from considerations of an entirely different character, concluded quite recently that our Solar System is revolving probably around a center with a period of *twenty million years.*]

The greatest proper motion yet observed is that of the Star 1830 Groombridge. Its present velocity is no less than *one million* feet per second. If this star is moving with this velocity in a circular orbit, or is moving in an elliptical orbit of any eccentricity, and is at present at its nearest distance from the center of the universe, our equation (3) will determine either the radius of its circular orbit or the length of the major semi-diameter of its elliptical orbit, by substituting in such equation

$v = 1{,}000{,}000$, and solving for ρ. Doing this, we get, approximately,

$$\rho = 1364 \times 10^{13} \text{ miles} = 2200 \text{ light years},$$

which, being within reasonable estimates of star distances, shows not only the sufficiency, but the plausibility of our hypothesis to account for the amount of proper motion observed in stars.

If the ether is ponderable matter, of course, it is only natural that it should be also the physical basis of the universe out of which nebulas and stars were born; and we may picture before our minds the universe, in the first stage of its appearance in infinite space, as an immense ethereal nebula obeying the law of universal gravitation.

Beginning at the time when ordinary nebulas, and even stars, started to make their appearance in such universe, all bound towards its center, one of the inevitable results must have been the appalling collisions of many of these bodies in reaching this destination, spreading fragments and cosmical dust, vivid with light and heat, in every direction, to great distances. The bodies which, by a happy *contre-temps* in starting on their eventful journeys, passed the center of the universe unharmed, must have necessarily met with other bodies coming from opposite sides, towards this center, at various distances from it. Some collisions must have occurred, giving place to larger bodies animated by a more or less rapid motion of rotation, and in many cases these collisions must have scattered fragments to great distances in directions crossing with those followed by the previous fragments emanating from the center of the universe. By mutual attraction, many of these fragments must have combined into small systems endowed with considerable kinetic energy of revolution, but all bound to reach the center of the universe at some future time. The bodies escaping collision after passing through the center of the universe, and the bodies coming towards this center, must have acquired great relative velocities when passing close to each other. Imagine two such bodies in the act of passing by one another. Their mutual attraction must, inevitably, have forced them out of their rectilinear paths, causing them to revolve, each in an elliptical orbit of large eccentricity, one body moving in one, the other in the opposite direction around the center of the universe; and it seems natural to admit that, without going through this process, a star or a nebula would have very few chances to continue its existence.

The passage of bodies close by each other, but at considerable distances from the center of the universe, would give them very much less relative velocities than in the case just contemplated, and consequently must have opened a field for the formation of binary systems. These systems, however, being still bound for the center of the universe, must have ultimately met their fate there, and must have started the formation of a great central mass endowed with motion of rotation, to be swelled later on by the fall of the innumerable fragments, or systems of them, already on their journeys towards the great center of attraction.

From what has already been shown, it can be reasonably inferred that in the evolution of such universe, the surviving stars and nebulæ would, almost without exception, be found to revolve in elliptic orbits of various dimensions and eccentricities, with different velocities, around the center of the universe; that the planes as well as the axes of these orbits would be found to intersect each other at all imaginable angles; that the motion of stars and nebulæ in their orbits would be found to take place in every conceivable direction; that stars and nebulæ moving in elliptical orbits, when passing each other close enough and with a proper amount of relative velocity, would give place to binary and multiple systems; and that, finally, the perspective of the proper motion of stars and nebulæ, so organized, would, from any point of view, appear bewildering and confusing in its aspect.

Going back to the great rotating mass accumulated at the center of the universe, there was only one possible future for it, and that was a gradually increased rotation by condensation, the expanding into an immense disc extending to great distances, and finally, the breaking up of such disc into millions of stars, all revolving in the same direction around the center of the universe. These stars may well represent the Milky Way.

Stars and nebulæ on each side of this Milky Way must have been more or less affected by its attraction, according to distance, and must have gradually approached towards its plane, forming a condensation of stars diminishing from this plane towards its poles.

We need go no farther into details to show how forcibly the dynamics of stars follows under the hypothesis of a ponderable ether as the physical basis of the visible universe; and in a separate paper, now in course of preparation for another publication, we propose to show that this hypothesis is perfectly compatible with the functions ether is supposed to perform, and is also sufficient, without the intervention of any other law, but the one which governs the motion of planets and comets in their orbits around the sun, to account for almost every phenomenon we are acquainted with in molecular physics and molecular dynamics.

THE FRANKLIN INSTITUTE.

Stated Meeting, Wednesday, September 15, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

ON AN IMPROVEMENT IN THE ART OF GALVANIZING.

BY GEORGE C. REESE.
Member of the Institute.

The object of this paper is to call attention to a recent advance in the art of galvanizing, by which many objectionable features are obviated, which have heretofore characterized the methods of manufacturing generally in use, thereby insuring not only greater rapidity of production, better quality of product, economy in fuel, labor, capital, interest and other charges, but also resulting in the production of new forms of galvanized wire or coated material heretofore unknown to the trade.

For certain special uses of iron and steel, it is desirable, in many cases, to give the metal a coating which will be a protection from oxidation, and at the same time facilitate the uniting of different parts by soldering the coatings together. This is effected by immersing the iron, after it has been properly cleansed and prepared, in a bath of molten zinc, whereby a coating of zinc is obtained which firmly adheres to the iron, by reason of the alloying action between the two metals. This operation is universally known as galvanizing (which, it may be remarked incidentally, is a misnomer), and differs very little from tinning and lead coating.

The protection from oxidation, in galvanized wire, is fully accomplished when a very thin and uniform coating is obtained; but where the wire is afterwards to be subjected to twisting and bending, such as twisting the ends of telegraph wires together, or the weaving of wire cloth, the wire should be soft and the zinc as pure as possible, so that the elongation of the two metals is as nearly equal as possible, otherwise the coating is liable to crack and peel off.

In galvanizing, it is necessary that the iron operated on should remain in the bath until it acquires the same temperature as the molten metal, or the coating will not adhere; this, in the case of galvanized wire, necessitates the maintenance of large tanks of molten zinc, containing often as much as 50 to 60 tons of metal.

In the usual method as heretofore practiced, a number of previously prepared wires are drawn slowly through the molten bath of coating metal, and, upon emerging therefrom, are passed through tightly enveloping wipers of asbestos or other material to remove the excess of coating upon their surfaces. This method is necessarily slow, because the time of transit through the bath is fixed by the fact that the temperature of the wire must be raised to, or approximately to, that of the spelter in order that it may receive a thin, durable coating; and also because of the frequent breakage of the wires from the tension exerted upon them by the action of the drawing and reeling devices.

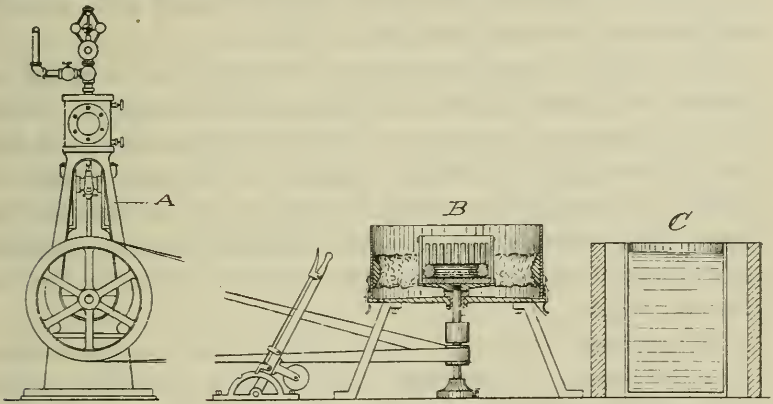
The speed at which No. 12 wire is coated being from about

50 to 60 feet per minute, this gauge runs from ¼ to ½ mile, and smaller gauges several miles in length, per bundle. Hence, although many devices have been adopted for increasing the production and decreasing the breakage, by complicated apparatus for drawing larger numbers of wires through the bath and the wipers, and by giving notice of undue strain exerted upon the wires by tension, the output of each bath was and necessarily will be low, in the use of this old method. This in itself called for the use of a large number of galvanizing pots in order to bring up the output of the factory to the paying point. Any increase in the speed of drawing inevitably requiring a corresponding increase in the length of the pots because the time of transit through the bath could not be shortened below the limit before mentioned.

The constant maintenance of an enormous tonnage of spelter in a fluid condition, constantly exposed to oxidation and to the destructive alloying action of the metallic surfaces of the pots, entailed great loss, trouble and annoyance by the rapid formation of "dross" and oxides. The percentage of dross should be kept as low as possible to insure proper fluidity and working of the bath. This dross consists mainly of spelter, which granulates after alloying with a very small percentage of iron, and, being heavier than the pure spelter, sinks to the bottom of the bath. Its formation, in conjunction with the necessity of drawing the wires slowly through long, deep, wide baths, has entailed great loss.

It will be seen, therefore, that the method of drawing wire through a bath and wipers is radically defective in its principle of operation, of progressively subjecting succeeding portions of the coating to the action of the wipers by tension, apart from any defects in apparatus used for such purpose; yet, notwithstanding, it has continued in use as the only practical method heretofore known to the art for giving a good and reasonably uniform coating to ordinary or fine wire.

By a newly patented method, the practicability of which has been demonstrated at the works of the Sharon Hill Galvanizing Company, Darby, Pa., the samples of coated wire which are now exhibited for your inspection are some of the many forms in which wire can be coated in a cheap, rapid and efficient manner, at a speed heretofore impossible to attain, and of a quality, uniformity and finish of coating unequalled by that of the wiping process. This is done by a method of operation which absolutely prevents the breakage by tension and the imperfect ends which occur in the wiping method; it obviates also the necessity of keeping a large tonnage of spelter constantly heated and exposed to the formation of dross by alloying and oxidation, reduces investment, capital, interest, fuel, labor and other incidental charges, and enables the manufacturer, with a small cheap plant, to exceed the output of the large costly plants now in use. The securing of these results is obtained by a radical departure from the principle of operation of the old wiping method of progressively applying tractive force to successive parts of the wire or bundles; and in lieu thereof each and every part of the coating upon the wire is simultaneously subjected to the action of a centrifugal strain greater than the combined adhesive and capillary attraction acting to retain the superfluous material upon the surface of the wire or between the strands of the bundle, thereby leaving a smooth, flexible, adherent and uniform coating upon the surface of the product. This is effected by means of an apparatus shown herewith, in which *A* represents the motive power, *B* a centrifugal separator, which is



A, motive power ; *B*, centrifugal separator ; *C*, spelter pot.

generally known as a hydro-extractor, and *C* the galvanizing bath.

The coils or bundles of wire are cleansed by acid and prepared in the usual manner to receive their coating. A whole bundle is then dipped into the bath of melted spelter, and when it has received a thorough coating, it is removed to, and dropped into the centrifugal separator, which may be in motion for small light coils, or the machine may be started after heavy bundles are placed in it. After a short space of time the wire attains the same speed as the machine, and the surplus coating is almost instantly thrown off against the safety shield. The machine is then stopped and the bundle removed. This part of the process is performed as quickly as possible, in order that none of the coating may solidify until after its removal from the machine.

The wire is then subjected to an operation designed to prevent the strands from becoming welded together when such solidification takes place. This is accomplished by jarring the bundle on a block to keep the different strands in motion or separated from each other, or by unwinding the bundle and rewinding it in such a manner that the coating may solidify while in transit from the unwinding to the rewinding reels.

In practice it has been found that a speed of 750 revolutions per minute is sufficiently high to do good work on No. 20 wire in bundles of 10 inches diameter. Larger gauges require less speed, on account of retaining the heat longer and because less capillary attraction is exerted where the spaces between the wires are greater; variation of the initial heat of the bath also causes variation in the cohesive force of the spelter, and variation of the chemical constituents of the bath is also a factor, as some baths work more fluid than others at a given temperature. Smaller gauges of wire and smaller bundles also call for an increased speed of rotation; but in general, I have found that the minimum and maximum speed of rotation required, are about 500 and 1,500 revolutions per minute when operating on 10-inch bundles.

The chief advantages of this method are as follows: As it is only necessary to subject an entire bundle of wire for a few seconds of time to the action of the centrifugal separator instead of drawing a small number of strands through wipers at the slow speed of not more than 1 foot per second, as in the old wiping process, the bundles are finished as fast as they can be raised to the proper temperature and coated in the galvanizing bath, hence the tonnage output, per pot, is enormously increased, especially so on fine wires, some of which are many thousands of feet in length to the single pound, and which could not be made for general consumption on account of the prohibitive price of such galvanized product. The great increase of product from each pot renders few of them necessary in plants of large tonnage capacity, thereby saving a large proportion of the first cost, cost of repairs, fuel and labor. As few and comparatively small pots are used, but little spelter is required to be kept constantly in a molten condition, subject to continual oxidation and the formation of dross from the alloying action of the metal of the pots. The large amount of capital heretofore required to purchase and maintain in a fluid condition the enormous tonnage of spelter in comparison with the output, is not required for such purpose. Like the old wiping process, it produces a smooth, uniform, flexible coat of galvanizing material upon the wire, but has the advantage of having no breakage from tension and no waste ends on the bundles; finally, it saves capital on account of diminished labor, fuel consumption and power, concentrates the size of plant, requires less ground, fewer buildings, repairs, etc., and enables the manufacturer of galvanized wire to produce, in a cheap and rapid manner, many forms of wire heretofore unknown to the trade.

Among the new articles produced by this method is barbed wire, which has been galvanized after it has been twisted into shape and formed into bundles. When wire is galvanized before being barbed and twisted, much of the coating cracks and peels off and the points of the barbs, where they are not coated, become blunt by rusting. This new article, can not only be produced much more cheaply, but is also more durable, and, as the points of the barbs are completely coated, it retains its efficiency much longer than the old kind.

Twisted fence bands are rapidly galvanized in the bundle, by this method, after they are formed.

The samples of wire rope here shown illustrate in a remarkable manner how perfectly the superfluous coating material may be eliminated by centrifugal action, and yet leave a perfect coating upon the wires.

Wire cloth is galvanized by the old method from two meshes to eight meshes per lineal inch; but in cloth finer than eight meshes so many of the meshes become permanently closed with the coating material, that it is impossible to produce a marketable article. By the new method cloth of any fineness may be coated if the speed of rotation be increased with the fineness of the cloth operated on. I have here samples of 12 x 13 fly wire and No. 16 mesh, which I believe was the first cloth of this kind ever successfully galvanized after being woven.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 15, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 15, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 83 members and visitors.

Additions to membership since last report, 7.

The Actuary submitted the following preamble and resolutions as the action of the Board of Managers on the resolutions relating to the Smoke Nuisance, submitted to the Board by the meeting of May 19, 1897, viz.:

Whereas, The Board of Health of the City of Philadelphia has requested the Franklin Institute to discuss the question of Smoke Prevention, and to offer practical suggestions relative thereto; and,

Whereas, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and,

Whereas, It appears from testimony presented to the Institute that it is practicable to burn bituminous coal in suitably constructed furnaces without creating a smoke nuisance;

Therefore, Be it resolved, that it is the opinion of the Institute that the continuous or frequent discharge of dense black smoke from furnaces of stationary boilers is avoidable, and should not be permitted within the city limits.

Resolved, That the emission of smoke from locomotives and furnaces other than those of stationary boilers, might be greatly reduced if the co-operation of firemen and employers were enlisted with an earnest intention to abate the nuisance, and more especially could the railway companies be induced to use anthracite coal or coke in the furnaces of the locomotives used for local service in the train-yards within the city limits.

Resolved, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health, and to the Presidents of City Councils.

On motion of Mr. Wm. H. Thorne, duly seconded, the preamble and resolutions were adopted without dissenting vote.

Vacancies in the Committee on Science and the Arts, reported by the Secretary, were filled by the election of Mr. Wilfred Lewis for the unexpired term of Mr. John H. Cooper, deceased, and Mr. W. C. L. Eglin for the unexpired term of Mr. N. H. Edgerton, resigned.

Mr. George C. Reese, of Darby, Pa., made a communication describing certain improvements in galvanizing, which he had invented, and exhibited a number of samples of work. (Referred for publication.)

The meeting then proceeded to the special subject of the evening, namely, the presentation of descriptions of improved furnaces and automatic stokers. Communications were presented from the following: Babcock & Wilcox Company, New York; Mr. W. R. Roney, describing the Roney automatic stoker, manufactured by Westinghouse, Church, Kerr & Co., of New York; Mr. W. R. Tatnall, representing the Hawley Down-Draught Furnace Company, of Pittsburgh; Mr. Wm. H. Thorne, representing Messrs. Wm. Sellers & Co., Inc., manufacturers of the Vickars automatic stoker; and Mr. Alfred Wilkinson, representing the Wilkinson Manufacturing Company, of Philadelphia, manufacturers of the Wilkinson stoker.

The various speakers illustrated their remarks with the aid of models and lantern slides.

A number of communications, bearing on the same subject, were postponed until the stated meeting of October 20.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held September 1, 1897.*]

MR. G. MORGAN ELDRIDGE in the chair.

Reports on the following subjects passed first reading:

A Testing Machine for Measuring the Intensities of Impulsive Forces. B. W. Dunn, Lieut. U. S. A., Frankford, Phila.

Process of, and Apparatus for, Manufacturing Mosaics, etc. Herman C Mueller, Zanesville, O.

Arndt's Econometer, Joseph Wilckes, New York.

Cazin's Percussion Wheel, American Impulse Wheel Company, New York

Improvements in Vehicle Wheels, E. L. Markley, Royersford, Pa.

Reports on the following subjects were adopted :

Rochester Time Recorder —Willard & Frick Manufacturing Company, Rochester, N. Y.

ABSTRACT.—This invention provides a means by which a workman personally records upon his individual time-card the time when he enters and leaves the workshop. The device is controlled by a clock, and the system of operation renders unnecessary the services of a clerk or timekeeper. (For special details the report must be consulted.) The report speaks very favorably of the simplicity and effectiveness of the recording mechanism, and also of the simple and inexpensive card system employed, and concludes that the invention represents a decided advance in time-recording systems. The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—H. R. Heyl, J. M. Emanuel, Charles James.]

Window Ventilator.—Percy A. Sanguinetti, Philadelphia, Pa.

ABSTRACT.—The device is intended to secure better ventilation of existing apartments, and consists essentially of a deflector of wood or other material extending the full width of the window, and supported at its ends by metal plates, which are secured to the sash-beads. The deflector rests in grooves contained in these plates, which govern also the changing the angle at which the deflector may be set. Separate grooves provide for the insertion of a wire screen for intercepting dust.

The object of the apparatus is to admit fresh air under the sashes of windows, to which it may be attached, and at the same time to deflect it upwards so that it will diffuse and not cause disagreeable draughts.

The report finds that the use of deflectors similar in purpose to that employed in this device have been known and used prior to the date of the Sanguinetti patent, but admits the novelty and utility of the method of adjusting and securing the deflector at any desired angle. [*Sub-Committee.*—Stacy Reeves, Charles L. Hillman.]

Step-up and Step-down Transformer System of Electric Distribution.—Rudolph M. Hunter, Philadelphia.

ABSTRACT.—The report deals with the claim of the applicant for an invention of a method of transmitting power by means of step-up and step-down transformers, and deals chiefly with the consideration of the claims of the U. S. letters-patent No. 460,071, September 22, 1891, and collateral evidence submitted by applicant as to priority of invention. The report concludes that the evidence submitted is not sufficient to substantiate applicant's claims. [*Sub-Committee.*—Clayton W. Pike, Chairman, E. A. Scott, Carl Hering, Thomas Spencer, H. W. Spangler, L. F. Rondinella, Paul A. Winand.]

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A PHOTOGRAPHIC IMPACT TESTING MACHINE FOR MEASURING THE VARYING INTENSITY OF AN IMPULSIVE FORCE.

BY B. W. DUNN,
Lieut. Ordnance Department, U. S. Army.

INTRODUCTION.

The usual classification of variable forces as impulsive and non-impulsive depends upon their rates of change of intensity.

As ordinarily understood, an impulsive force is one whose intensity changes too rapidly to permit successive measures of it. The main object of all engineering and structural work may be said to be the supplying of adequate resistances to neutralize dangerous forces, and as this cannot be done satisfactorily until the maximum values of these forces are known, it is thought that no apology is necessary for any proposition that promises to advance, be it ever so slightly, our capacity to measure forces.

There are two methods for such measurement, the static and the dynamic methods. The former, which is quite limited in its application, consists essentially in balancing the unknown force by a known one. The latter, which is the true scientific method, requires the accurate measurement of extremely minute intervals of time and space.

The practical measurement of forces has shown but a few applications of the dynamic method, since no apparatus possessing the required delicacy and accuracy has been available. As a direct consequence of our inability to measure impulsive forces, they are found by engineers to be the most dangerous, and our constructions are liable to show unnecessarily high factors of safety and waste of material on the one hand, or break-downs with their disastrous consequences on the other. The forces developed by blows furnish the most striking examples of impulsive forces. The engineer is compelled to measure a blow in *units of work,* although he knows that the ability of his structure to stand the blow depends upon the *maximum intensity* of the stress developed. In exceptionally favorable cases he may be able to measure the mean stress, but this is of comparatively little use to him.

This necessity for passing from units of intensity to units of work in measuring a blow has produced a great deal of confusion. It has caused the average mechanic, and even the average engineer, to think and to speak inaccurately on the subject of blows. How frequently do we hear, in discussions of applied forces, the expression, "Ah! but there we have no longer a pressure, it is a blow!" The speaker evidently thinks that a wide gulf separates a blow from a pressure. He can understand a pressure and anticipate its effect; but the mere fact that a blow is delivered is sufficient, in his mind, to account for any observed effect, and to remove the matter at once from the field of accurate, scientific discussion. This popular misconception should be removed. There is no difference between a blow and an equivalent pressure except in the matter of time. The blow produces its maximum pressure in an inconceivably short interval of time, and the static testing machine cannot tell us what that maximum was. We know that the slightest variation in conditions of blow may affect largely the maximum pressure developed, and that this pressure is especially susceptible to differences in duration of blow.

When required to neutralize the effect of an impulsive force the engineer should have information on two points, viz.:

(1) He should know the maximum intensity of the force.

(2) He should know the physical qualities of resisting material *when subjected to impulsive forces.*

It is a mistake to assume that a piece of metal, or other material, will show the same effect when subjected, on the one hand, to a given force applied slowly—as in a static testing machine—and, on the other, to the same force applied and withdrawn within thousandths or tens of thousandths of a second.

Is it possible to construct a practicable impact testing machine capable of furnishing the above-described information? From the experience gained and the success attained in investigating a special problem, the writer is inclined to answer this question in the affirmative, and a description of this special investigation is thought to be the best way to place the reader in a position to judge for himself.

DYNAMIC MEASURE OF PRESSURE PRODUCED BY A BLOW.

An instrument, called the crusher gauge, is used to measure the maximum pressures developed by the expansive force of fired gunpowder. It consists, essentially, of a housing which screws into the face of the breech-block and encloses a small cylinder of pure annealed copper, half an inch long and a quarter of an inch in diameter. A hard steel piston (area one-tenth of a square inch) moves in a gas-tight channel in housing and transmits the powder pressure to copper cylinder.

The effect of the pressure is to shorten the cylinder, and the exact amount of shortening is determined in each case by micrometer measurements made before and after firing. This shortening, or compression, is translated into maximum powder pressure by means of a "tarage table" constructed from static testing machine data. This data is obtained by compressing a series of similar cylinders in a static machine and recording the mean loads required to produce the successive compressions. Suppose, for example, that the static machine shows a load of 4,500 pounds to be necessary to compress the cylinder 0·2 inch, *i. e.*, to change its length from 0·5 inch to 0·3 inch. It is assumed, then, that the maximum powder pressure on piston is 4,500 pounds—45,000 pounds per square inch—when the effect of it is to produce this 0·2 inch compression in the copper cylinder.

There are many interesting details concerning the construction and use of crusher gauges that cannot be given here. It is desired only to show that the gauge furnishes an excellent example of the enforced neglect of the element of time in measuring forces. The military engineer has been compelled to assume that the compression produced in this copper cylinder by a given pressure, applied slowly in the static machine, is identical with that produced by the expansive force of powder gases, applied and withdrawn within a few thousandths of a second. Theoretically, the effects cannot be the same. To produce compression, an appreciable mass, even in the copper cylinder itself, must be moved, and this requires time.

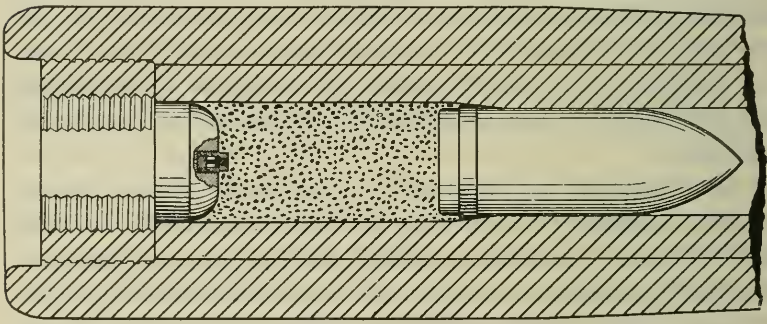

Fig. 1.

During the spring of 1891, the writer conceived the idea of compressing this copper cylinder by means of a blow and securing a dynamic measure of the cylinder's successive resistances.

By a proper selection of the mass and impact velocity of striking weight, any given compression can be produced in about the time consumed in producing the same compression in the gun.

Let us assume, for the present, that we have an apparatus which will record for us a curve such as is shown in *Fig. 2.*

The ordinates of this curve represent the successive shortenings of copper cylinder, during the delivery of blow, or the distances passed over by the weight after impact. The corresponding abscissas represent the times from instant of impact. The ordinates are separated by equal times, each equal to the smallest interval of time that can be accurately measured. This small interval is the unit of time, Δt, used in measuring the total duration of blow. Since this total duration is to be limited to a few thousandths of a second, it is evident that our unit of time, Δt, must be extremely minute if we are to divide the total compression into a great number of parts. The differences between the successive ordinates divided by the time, Δt, enable us to measure the successive velocities of the weight after impact. The differences of these successive velocities, divided by Δt, give us the successive

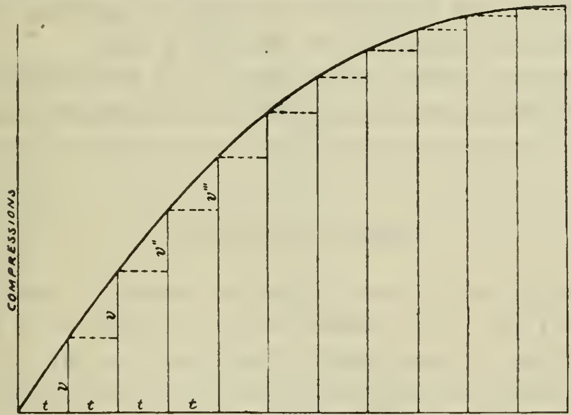

FIG. 2.

changes in weight's velocity, or the retardations due to copper resistance. The products of these retardations by the mass of weight measure the successive resistances of copper cylinder.

The process amounts simply to a graphical differentiation of the impact compression curve recorded as a function of the time of compression..

To obtain, in this way, a measure of the varying pressure produced by a blow, we must construct an apparatus capable of measuring simultaneously, and with the greatest accuracy, extremely minute intervals of time and space.

For all such measurements the first requisite is means for accurately *magnifying* the quantities to be measured. Only those who have had the experience can thoroughly appreciate the difficulties that had to be overcome in supplying an apparatus capable of dissecting the effect of a blow.

Let us trace briefly and separately the development of the time- and distance-measuring parts of the completed apparatus and then show their combination for simultaneous use.

TIME MEASUREMENT.

A tuning fork is used almost universally to subdivide a second of time. The method usually adopted is to attach a pen, or stylus, to one prong of the fork (see *Fig. 3*) and to cause a smooth metal surface, coated with lamp-black, to be drawn past the vibrating fork. The point of pen, by plowing through the lamp-black and exposing the bright metal surface, records a waving line, called a sinusoid. If the surface be drawn past while the fork is at rest, a straight line, called the median line, is produced. The width of record represents the fork's amplitude. The measured distances between the intersections of these lines show how far the recording surface moved during a whole or a half vibration of the fork. For smaller intervals of time it is usually assumed that the velocity of surface remains constant for the vibration interval.

It will be seen that the accuracy of time measurement will increase directly with:

(1) The rate of the fork—a fork that divides a second into

1,000 parts being preferable to one that divides it into only 100 parts, just as a scale showing hundredths of an inch is preferable to one showing only tenths.

(2) The velocity of recording surface. If we have 1 inch as the distance equivalent of the time of one vibration of fork, we can pass more accurately to a given fractional part of this time than we can when this distance equivalent is only one-tenth of an inch.

(3) The clearness of intersections of median line and sinusoid.

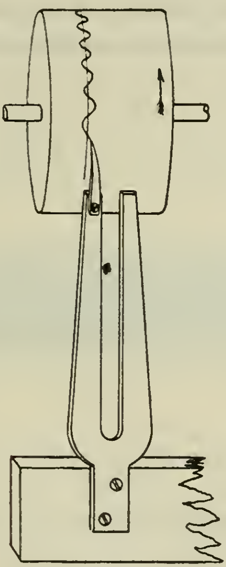

FIG. 3.

The upper record in *Fig. 4* illustrates the use of a slow fork with large amplitude. The median line and sinusoid intersect at an obtuse angle, and it is easy to fix the points of intersection. The next record illustrates the substitution of a fork twice as fast as the first one. We thus divide a second into twice as many parts, but the amplitude decreases with an increase in rate of fork, and we observe a greater chance for error in fixing the points of intersection. The same trouble would follow a doubling of the velocity in recording surface.

If we continue to increase either the rate of fork or the velocity of recording surface, we shall obtain a result illustrated by the third record, wherein great difficulty would be experienced in fixing the points of intersection.

These conditions limit us, in the stylus method, to a fork of about 500 complete vibrations per second, and to a velocity of recording surface of about 10 feet per second.

It was evident that the above-described method would not meet the conditions imposed upon the projected impact testing machine, and the writer entered, during the summer of 1891, upon the development of a new and an improved method. After successive steps, which involved a great many experiments, it was decided to substitute a sensitized photographic surface for the lamp-blackened metal surface and a beam of light for the stylus attachment to the fork.

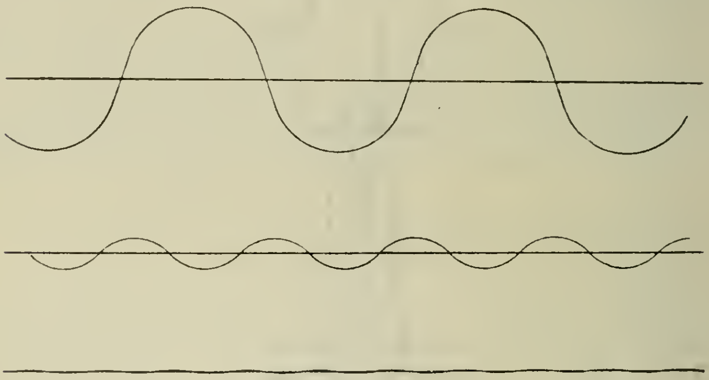

FIG. 4.

The resulting time scale is illustrated by *Fig.* 5.

A hole with perfectly smooth edges is bored in the end of fork and illuminated by a concentrated beam of light. A lens placed between fork and sensitized surface produces a sharp and a magnified image of the edge of this hole. As the fork vibrates, the image moves up and down on the horizontally moving surface. The diameter of circular image is greater than the horizontal distance traversed by sensitized surface during the time of one vibration of fork.

Instead of being limited to $\frac{1}{500}$ of a second, the main divisions in this scale represent less than $\frac{1}{4000}$ of a second, and the velocity of recording surface was about 100 feet per second, instead of 10. The troublesome intersections of median line and sinusoid are here replaced by the intersections of the up-and-down curves, readily determined by causing the cross hair in microscope of measuring instrument to bisect the angle between curves. This operation is facilitated by the areas of double exposure in body of record, the points of which are directed toward these intersections.

When it is impracticable to secure uniform velocity in the recording surface—as, for example, when this surface is attached to a body having a varying motion which we wish to investigate—the main divisions in scale will be the smallest interval of time that we can measure accurately, and we should have as many sets of points separated by this interval as possible. In the stylus method we can get but two sets, since we have only one median line; but in the photographic record we obtain two sets from each shadow line. These shadow lines are cast by a grating of fine wires, or hairs, placed in close proximity to the sensitized surface and in the path of beam of light.

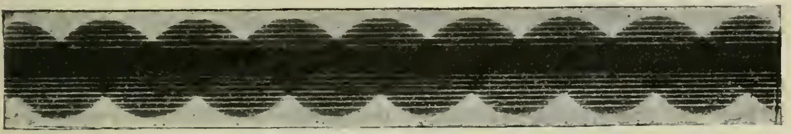

FIG. 5.

A more rapid fork could be used with equal facility, and the velocity of recording surface could readily be increased to 500 feet per second. By the method to be described later, this velocity can also be kept constant for a longer time than would be consumed in delivering the blow to be investigated. The use of a high fork is made practicable by the fact that we record not the actual amplitude of fork, but the amplitude of movement in the magnified image.

Our ability to magnify the amplitude without affecting the wave lengths in time scale, and our control of the relation of diameter of image to these wave lengths, will always enable us to cause the up-and-down curves in record to intersect at about a 45° angle, the angle most favorable to an accurate determination of these intersections. The limits, in stylus method, to rate of fork and to velocity in recording surface are removed at once, and the effect of this removal may be compared with the effect upon accuracy of distance measurement of substituting a vernier caliper for a carpenter's rule. It is not necessary to dwell upon the advantages resulting from the substitution of the smooth, sensitized, for the rough, lamp-blackened surface, nor upon the advantage of securing a record of its vibrations without requiring the fork to do the mechanical work involved in plowing through the coating of lamp-black.

With a uniform velocity of 500 feet per second in sensitized surface—and to obtain this velocity it will be necessary only to give a 12-inch cylinder 10,000 revolutions per minute—we can readily detect an interval of time as small as one-tenth of a millionth of a second.

When we begin to subdivide a second of time on the one hand, or to multiply the circumference of the earth on the other, we are unable, through absence of contrast, to appreciate through our senses the magnitudes of our results.

The smallest interval of time that photography enables us to measure is just about as much less than a second as the distance to the nearest fixed star is greater than the circumference of the earth, and yet it requires 3½ years for light from this star to reach us, the velocity of light transmission being 188,000 miles per second.

DISTANCE MEASUREMENT.

Fig. 6 illustrates the method devised to secure a magnified photographic record of the distance traversed by weight after impact, *i. e.*, the compression of copper cylinder during delivery of blow.

A hardened steel piston rests on the copper and a hardened steel plug is secured in the end of weight *W*. The downward motion of piston after impact follows the compression of copper cylinder, the diameter of piston being such as to prevent any appreciable compression in the piston under the maximum pressure developed.

The small mirror, *m*, revolves about a fixed horizontal axis, and is connected with the piston by link work in which the journals and pivots are ground to as accurate a fit as possible.

The cylinder, *C*, is rigidly mounted at a horizontal distance in front of mirror, determined by the magnifying ratio desired, and means are provided to revolve it at great speed about a vertical axis. The surface of cylinder is covered by a photographic film, a perfect glove fit being secured; or, if desired, the cylinder can be made of glass, ground true, and coated as the ordinary photographic plates are coated. A beam of light, after passing through a proper combination of lenses, is thrown on the small mirror, *m*, and reflected thence to the surface of cylinder, *C*. This beam traces its path on the sensitized surface and produces a curve whose ordinates are *magnified reproductions of the downward motions of piston and hence of the successive compressions of copper cylinder.*

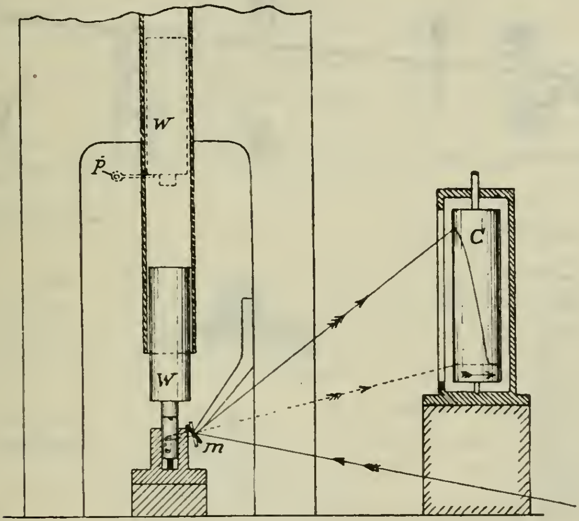

FIG. 6.

We thus obtain the *impact curve*, which needs only a time scale, parallel to axis of abscissas, to enable us to construct a pressure curve for the copper specimen which will show the actual resistance offered by the copper at each stage of compression.

SIMULTANEOUS MEASUREMENT OF TIME AND DISTANCE.

The skeleton drawing, *Fig. 7*, illustrates the combined and simultaneous use of time- and distance-measuring apparatus.

The experiments are conducted in a dark room, and the two required beams of sunlight are reflected through pipes, *p* and *p'*, from outside mirrors. The tuning fork is shown with a spreading wedge inserted between its prongs, ready to be withdrawn by impact of small weight, *w'*, on end of lever. The weight, *W*, which strikes the blow on copper specimen, is released by withdrawing the metal pin which sustains it in the vertical guiding tube. The lens, *L*, produces a small and

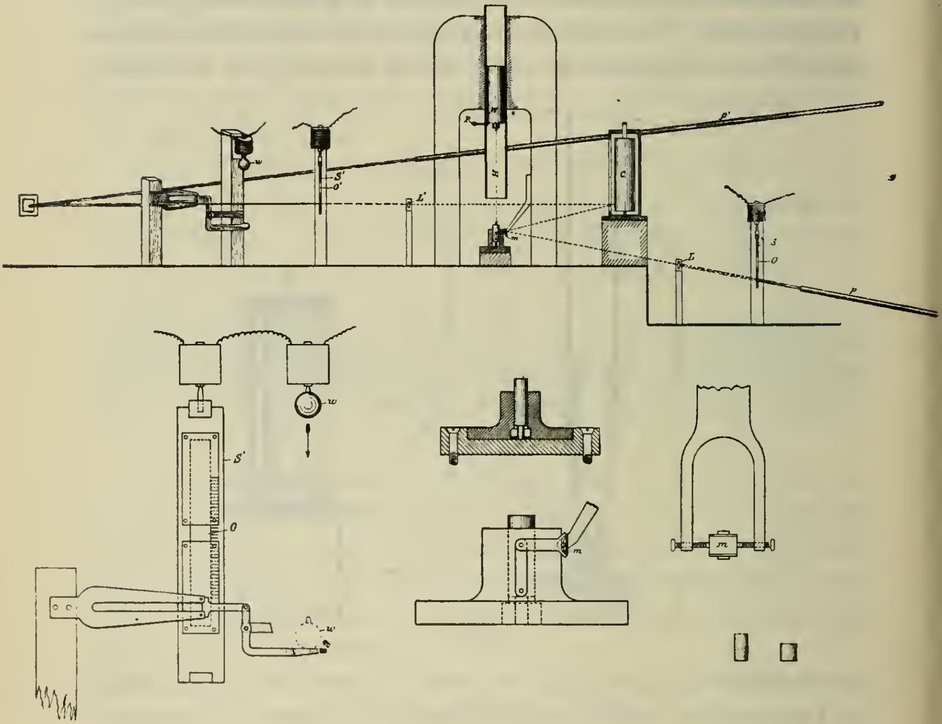

Fig. 7.

intense image of the sun on the surface of cylinder, C. This image moves upward during delivery of blow and traces the impact curve. The lens, L', produces a well-defined and enlarged image of the circular edge of hole in end of fork. This image traces the required time scale parallel to axis of abscissas of impact curve. These two beams of concentrated light must not be turned on until just before impact, and they must be turned off again immediately after completion of blow. In the experiments made, the cylinder, C, completed about 100 revolutions per second, and it required only about one-third of one revolution to produce the desired records. The height of fall of the weight, W, varied from 7 to 15 inches. Gravity shutters, S and S', are shown suspended from electro-magnets, and in the paths of beams of light. The front view of one of these shutters shows an adjustable opening, O. During the fall of shutter this opening passes the beam, permits the light to reach the sensitized surface for the required interval, and then shuts it off again. The magnets which sustain the shutters, S and S', and the small weight, w, are energized by a current which passes through the metal guide cylinder and the pin which sustains the weight, W. A rapid tuning fork will vibrate only a short time, and for this reason it was desirable not to withdraw the wedge from this one until about one-hundredth of a second before impact. The drawing does not show the means provided to rotate the cylinder, C. This consisted, at first, of an electric motor, which was discarded because the varying wave lengths in time scale showed that the rotation of cylinder was not as uniform as was desirable. The motor was then replaced by a system of multiplying cog wheels and a drum, the cord from drum passing to an auxiliary falling weight of about 100 pounds. The end of cord was not fastened to drum, so that, when unwound, the cord was entirely disconnected, and the cylinder was left with its maximum speed to be gradually reduced by friction.

The auxiliary weight was used to operate an adjustable trigger, which withdrew the metal pin, P, and released the weight, W, at a time such that impact of W on copper specimen occurred just as the cord became disconnected from drum. By this means the impact curve was recorded at the instant that acceleration in speed of cylinder, *C*, was passing through zero, and at this stage it was impossible to detect any variation in surface velocity. The frictional resistances being small, we should expect the rotation of cylinder, under these circumstances, to remain constant for the interval of time—not over 0·004 second—consumed in delivering the blow.

We can now trace the operation of this delicate mechanism.

After careful micrometer measurements of its length and its diameter, the copper cylinder is placed in position with the hard steel piston resting on it. The weight, *W*, is adjusted for the desired fall, which we will represent by *H*. The slides, *S* and *S′*, are suspended and adjusted so that the distance of lower edge of opening, *O*, above upper edge of beam of light, is less than *H* by a few hundredths of an inch, the exact difference being accurately calculated. A similar adjustment is made for the fall of small weight, *w*. The sensitized covering is placed over cylinder, *C*, and the wedge inserted between prongs of tuning fork. Assistants, outside the dark room, keep the reflected beams adjusted.

The apparatus is now ready to work automatically. The operator releases the auxiliary weight (not shown in drawing) and the cord which is attached to this weight begins to unwind from drum. The rotation of cylinder, *C*, communicated from the drum through multiplying cog-wheels, increases rapidly. When the auxiliary weight has fallen a determined distance it operates a trigger and pulls out the pin, *P*. The withdrawal of this pin releases the weight, *W*, and breaks the electric current, so that the shutters, *S* and *S′* and the small weight, *w*, begin to fall. A few thousandths of a second before *W* strikes its blow, acceleration of cylinder speed is stopped by disconnection of cord from drum, the weight, *w*, by its action on lever pulls out the wedge and sets the fork vibrating; the opening, *O*, in shutter *S*, is opposite its beam of light and the image of sun formed by this beam, after reflection from rotating mirror (which is now stationary, since impact has not yet occurred) begins to trace the axis of abscissas of impact curve; the opening in shutter, *S*, permits a simultaneous appearance of the vibrating image of hole in fork to appear just under the sun image, on same vertical element of cylinder, where it begins to trace a refined time scale.

When impact occurs, the copper specimen yields under the pressure developed; the hard steel piston follows up this yielding; the small mirror revolves at a rate depending entirely upon movement of piston, and the sun image moves upward in a vertical plane, reproducing, on a magnified scale, the successive compressions of copper specimen. The resistance to compression offered by the copper, working over the path of compression, gradually absorbs the kinetic energy in weight, *W*, and reduces the velocity to zero. A wave of elastic compression in copper precedes the permanent set. This elastic recovery is observed, in the static testing machine, to be practically constant and equal to about 0·002 inch. It causes the weight, *W*, to rebound, and, after second impact, to rebound again a lesser distance, and so on until it is finally brought to rest, supported on the steel piston. These secondary blows do not increase the permanent set in copper specimen, and they should not, since their impact energies can never be greater than the work in elastic compression, wherein is found the source of the rebounds.

An observer, standing in the dark room and looking toward the revolving cylinder, sees on its surface, at the instant of impact, a brilliant vertical line of light whose duration is less than that of a flash of lightning. The photographic film on the rapidly-spinning cylinder, however, has secured, during this inconceivably short interval of time, a permanent record of many important events and arranged them in chronological order, to be examined and studied at our leisure.

Fig. 8 shows a reduced reproduction of one of the impact curves.

In this case a 33·109-pound weight fell 15 inches and produced a permanent compression of 0·1658 inch in copper specimen. The time consumed in producing this compression was 0·0030317 second.

USE OF IMPACT CURVE.

To make the impact curve, *Fig. 8,* available for calculating a table to give the resistance, in pounds, for any given compression of copper cylinder in inches, it is necessary to know the rate of fork and the relation between any given ordinate of the curve and the compression of specimen. Photography was used to obtain this information, but space does not permit a detailed description* of methods adopted. The fork was calibrated by securing its record on a long photographic plate falling freely under action of gravity, and the variable ratio of ordinate to compression was determined from a series of "scale negatives" made by moving the piston down one-thou-

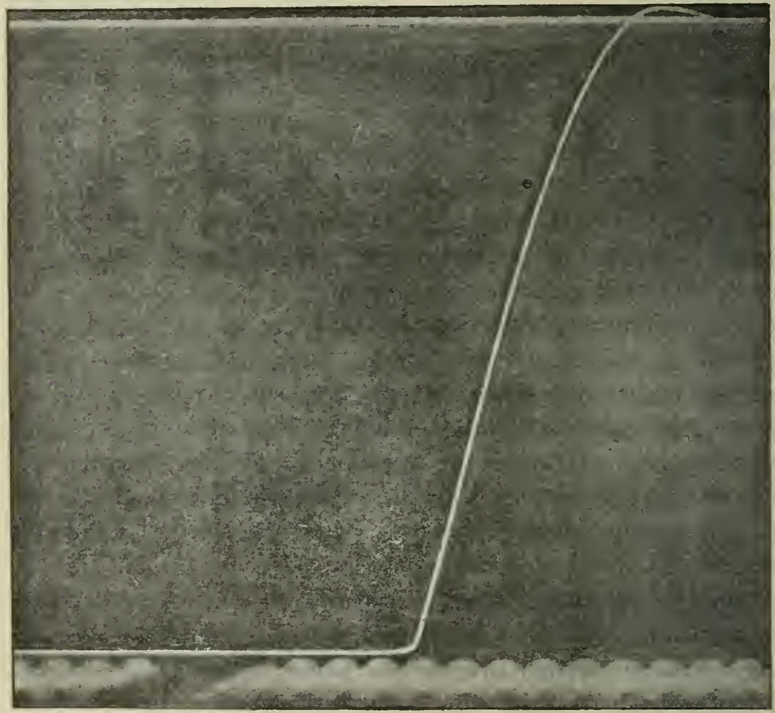

FIG. 8.

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* Detailed descriptions are given in "Notes on the Construction of Ordnance, No. 71, Government Printing Office, Washington, D. C.

sandth of an inch at a time and recording photographically the corresponding positions of "sun image."

With an instrument reading accurately to 0·00001 meter, a number of sets of ordinates, the individual ordinates in each set being separated by a constant and a small interval of time, Δt, were then measured and tabulated. The first differences of these ordinates measure the rate of compression, or velocity of falling weight after impact, and a curve can be constructed showing this velocity as a function of either time or compression. Each "set" of ordinates gives a "set" of points in this curve, and it is evident that we may obtain as many points as desired.

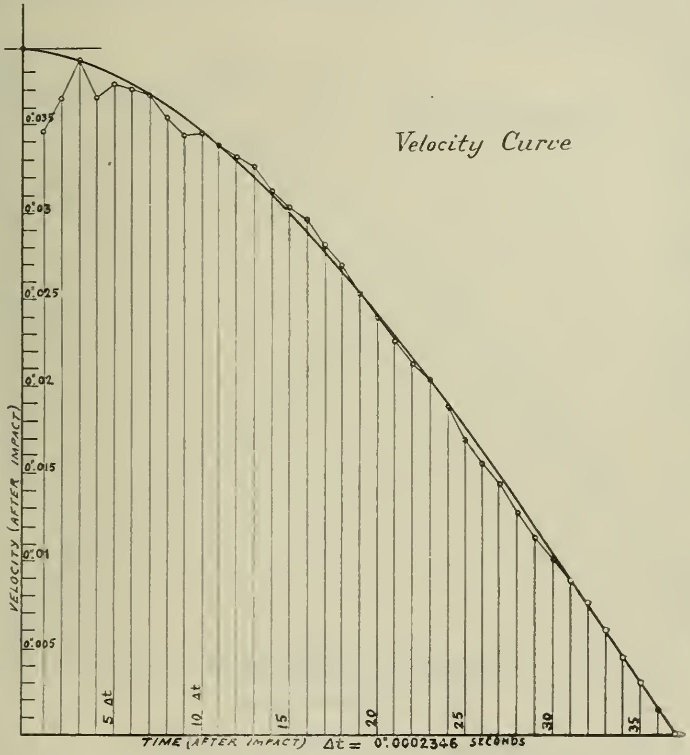

FIG. 9.

Fig. 9 shows a velocity curve constructed in this way for one of the negatives.

This curve was plotted on a very large scale, and the mean curve, assumed to be the true one, was easily drawn.

The true impact velocity and the initial tangent to curve are known from the height of fall of the weight, *W*.

The steel piston is at rest at the instant of impact, and requires some time to acquire the velocity of *W*. For this reason the initial measured velocities of piston are lower than the theoretical velocities of *W*, and the vibrations produced in apparatus by the shock from impact cause slight irregularities in the measured values.

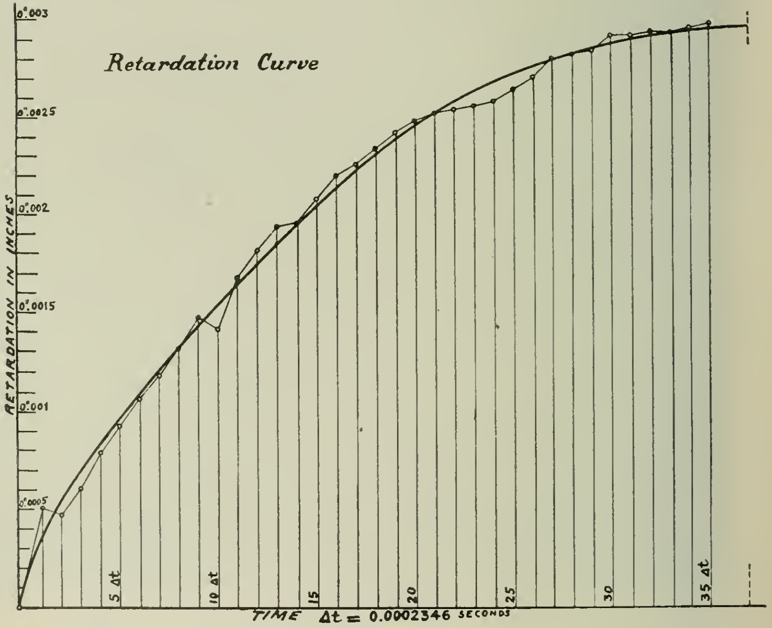

FIG. 10.

These irregularities are practically eliminated by the adjusted curve, and they do not appear during the final stages of compression. Since our main object is to obtain a reliable dynamic measure of the *maximum* resistance of specimen, the slight irregularities in measured data for the earlier stages are of little consequence.

After adjusting our tabulated "first differences" by the mean velocity curve, *Fig. 9*, we form another table showing "second differences" as a function of time, and use these data to plot the "retardation curve," *Fig. 10*. We know the initial and terminal tangents to the true retardation curve, and can readily draw the mean curve.

The analytical expression for the resistance, R, which, working over the path of compression, C, absorbs the kinetic energy in weight, W, is

$$R = -\left[\frac{W}{g}\frac{d^2 c}{d t^2} + W\right]$$

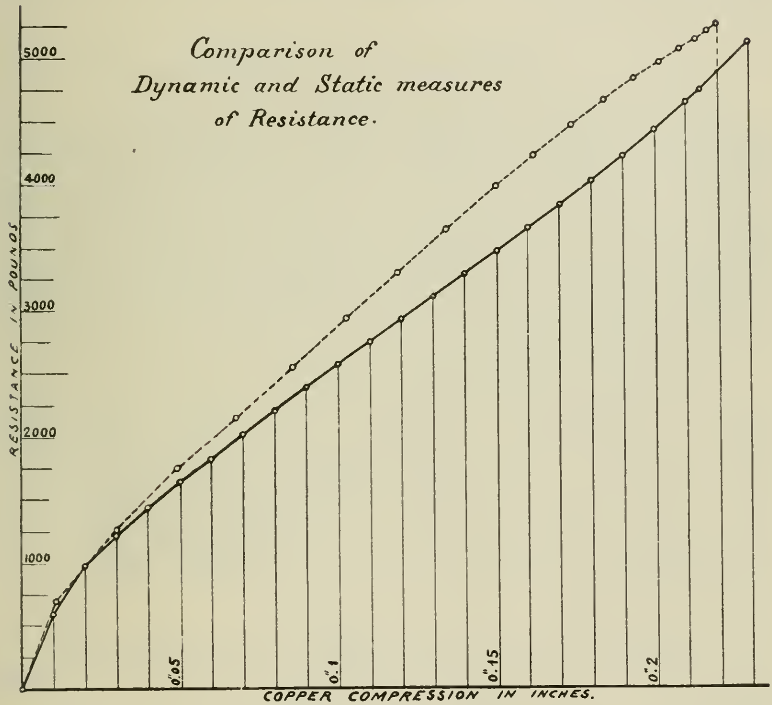

FIG. 11.

The ordinates of the retardation curve, *Fig. 10*, represent the variable factor

$$\frac{d^2 c}{d t^2}$$

By plotting, as a function of the compression, the values of R, obtained in this way, we obtain the dynamic resistance curve shown broken in *Fig. 11*.

For comparison, the same figure shows the resistance curve obtained from static testing machine data.

The difference between them represents the effect of the neglected "time element" or the error of "static tarage" when the total time consumed in producing the compression is about 0·003 second. This error will vary with the time, and it should also vary largely with the mass of specimen. The civil engineer who uses massive pieces to sustain impulsive forces is, therefore, interested in a further pursuit of investigations of this nature.

EMPIRICAL FORMULA FOR MAXIMUM RESISTANCE.

The foregoing sketch gives but a meager idea of the labor involved in using an impact curve to calculate the varying pressure produced by a blow. To secure the original measured data from the photograph requires time, patience, and a high order of skill in making fine measurements. The successive adjustments of data and the final calculations introduce further complications and restrict investigations of this nature to the field of laboratory research.

To be of practical value to the civil engineer this process must be simplified and abridged, so that within a short time after striking his blow the investigator may announce the maximum stress developed as well as the resulting strain. A very simple formula obtained by combining observed facts and theoretical deductions promises the desired relief.

This formula is

$$R = \frac{A\ M\ V}{T}$$

in which

R = maximum stress developed in a rigidly supported specimen by a blow.

$M\ V$ = quantity of motion in striking mass at instant of impact.

T = total duration of blow.

A = a coefficient whose limiting values are

1·57+

and unity. The value of this coefficient for a given blow will depend upon T and the material of specimen.

A brief outline of the study which furnished this formula is necessary to a thorough understanding of its utility.

In *Fig. 12* let the ordinates be resistances and the abscissas compressions.

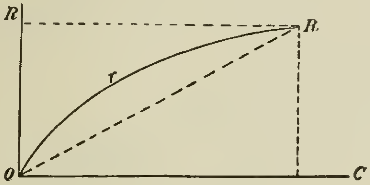

FIG. 12.

Let us assume, first, that the resistance increases directly with the compression, and that its initial value is zero. A right line, $o\,R$, will then represent the resistance curve. Under this assumption the relation of velocities of striking weight after impact to corresponding compressions will be that of the ordinates of an ellipse to the corresponding abscissas.*

---

* To show this, let us make in the ordinary equation of an ellipse,

$$a^2 y^2 + b^2 x^2 = a^2 b^2, \tag{1}$$

the following substitutions:

$y = v =$ velocity of striking weight after impact.
$b = V =$ velocity of striking weight at impact.
$x = c =$ compression of specimen.
$a = C =$ total compression,

we have,

$$C^2 v^2 + V^2 c^2 = V^2 C^2. \tag{2}$$

Differentiating, reducing and multiplying by M, mass of striking weight, we have:

$$M \frac{v\,d\,v}{d\,c} = R'' = -\frac{M\,V^2}{C^2}\,c. \tag{3}$$

Equation (3) shows that the resistance, R'', increases directly with the compression, c.

For the second assumption we substitute in the parabola equation,

$$y^2 = 2\,p\,x,$$

v for y, $C - c$ for x, $\frac{V^2}{C}$ for $2\,p$, and obtain for R' the constant value,

$$R = \frac{M\,v\,d\,v}{d\,c} = -\frac{M\,V^2}{2\,C} \tag{4}$$

On the other hand, let us assume the resistance as constant. A right line, such as *R R*, parallel to axis of compressions, will then represent the resistance curve, and the relation of velocities to compressions will be that of the ordinates of a parabola to the corresponding abscissas.

The middle curve in *Fig. 13* is the adjusted velocity curve of negative No. 22, plotted accurately as a function of compression. The upper curve is an ellipse, and the lower one is a parabola, both constructed to pass through the initial and final points of the true velocity curve.

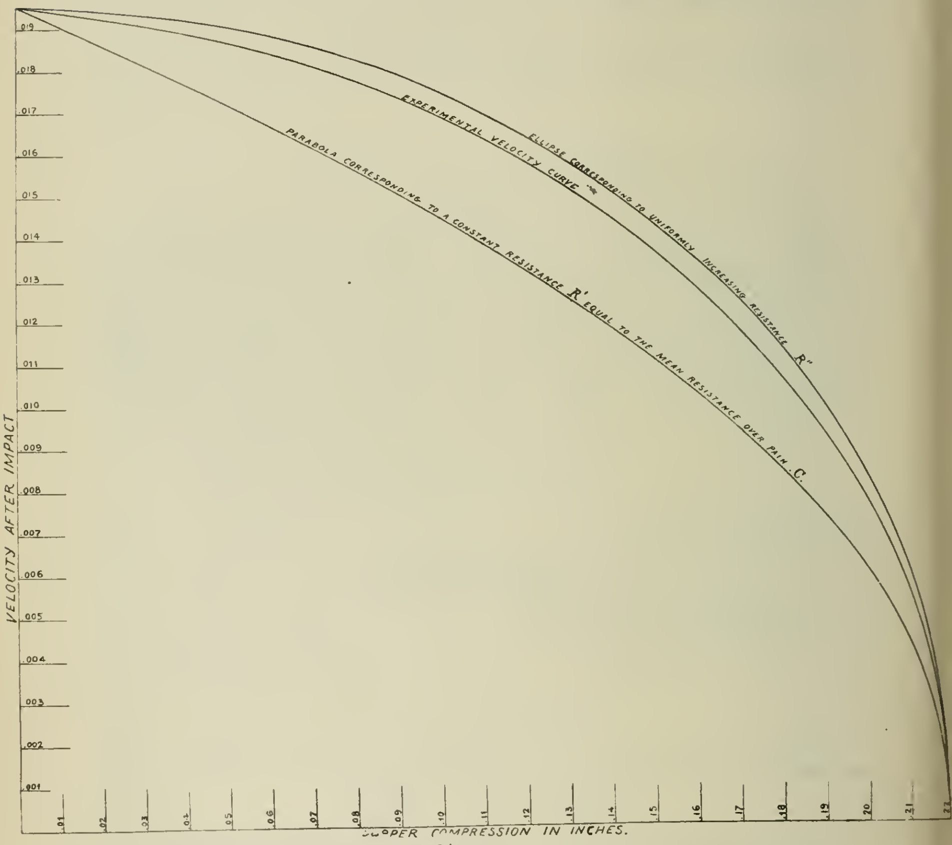

FIG. 13.

Since the true velocity curve, *Fig. 13*, lies between the ellipse and the parabola, we see that the true resistance curve will be some such curve as $O\ r\ R$, *Fig. 12*, and that the right lines, $o\ R$ and $R\ R$, corresponding respectively to the ellipse and to the parabola, *Fig. 13*, will be the limits.

The equation of the impact curve, as a whole, has not been determined. It can be represented by the equation,

$$t^2 = x\ c,$$

a parabola with a variable latus rectum.

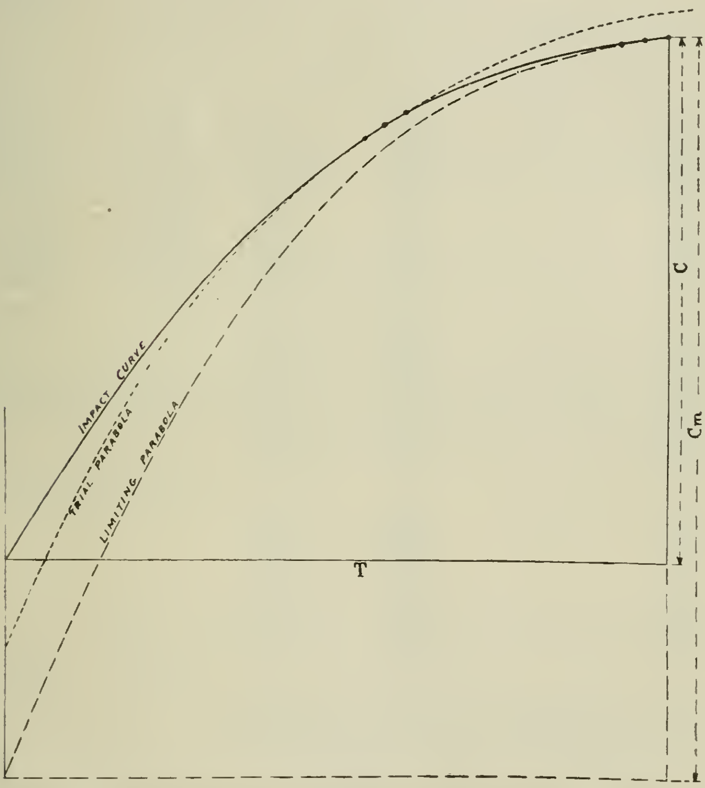

FIG. 14.

By selecting three points in impact curve, each separated by $\Delta\ t$, we can cause a parabola to pass through them and have its axes parallel to axes of impact curve.

Fig. 14 shows two such parabolas.

That parabola whose axis coincides with the maximum ordinate of impact curve is called the limiting parabola.

The following table shows that in the vicinity of the three selected points a parabola passing through them may be taken to represent the impact curve. The columns headed $\Delta c'$ and $\Delta c''$ show the differences between corresponding ordinates.

Measured Compressions.	Mean Compressions.	TRIAL PARABOLA. $t^2 = (5{\cdot}6207762 - 10)\,c.$		LIMITING PARABOLA. $t^2 = (5{\cdot}6006113 - 10)\,c.$	
		$0{\cdot}16995 - c'$	$\Delta c'$	$0{\cdot}16995 - c''$	$\Delta c''$
1	**2**	**3**	**4**	**5**	**6**
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch*	*Inch.*
·16995	·169923	·16995	·00000	·16995	·00000
·16992		·16992	·00000	·16992	·00000
·16990		·16998	+·00008	·16987	—·00003
·16983	. . . . . .	·16981	—·00002	·16980	—·00003
·16974	. . . .	·16972	—·00002	·16970	—·00004
·16965	. . . .	·16960	—·00005	·16959	—·00006
·16955	. . . .	·16947	—·00008	·16944	—·00011
·16940	. . . .	·16931	—·00009	·16928	—·00012
·16918	. . . .	·16913	—·00005	·16909	—·00009
·16899	. . . . .	·16892	—·00007	·16887	—·00012
·16872	. . . .	·16870	—·00002	·16864	—·00008
·16847	·168223	·16849	+·00002	·16842	—·00005
·16826		·16822	—·00004		
·16794		·16793	—·00001		
·16763	. . . .	·16762	—·00001		
·16729	. . . . . .	·16729	·00000		
·16698	. . . .	·16693	—·00005		
·16657	. . . .	·16655	— 00002	·16639	—·00018
·16619	. . . .	·16615	—·00004		
·16575	. . . .	·16573	—·00002		
·16529	. . . .	·16528	—·00001		
·16484	. . . .	·16481	—·00003		
·16440	·163887	·16440	·00000	·16413	—·00027
·16392		·15389	—·00003		
·16334		·16335	+·00001		
·16276	. . . .	·16280	+·00004		
·16208	. . . .	·16222	+·00014		
·16148	. . . .	·16162	+·00014		
·16089	. . . .	·16100	+·00011	·16057	—·00032
·16034	. . . .	·16035	+·00001		
·15957	. . . .	·15969	+·00012		
·15888	. . . .	·15900	+·00012		
·15814	. . . .	·15802	—·00014	·15773	—·00041

If the equation of limiting parabola be

$$t^2 = a\,c, \tag{1}$$

the value of maximum resistance, R (neglecting gravity), will be

$$R = \frac{M\,d^2\,c}{d\,t^2} = \frac{2\,M}{a} \tag{2}$$

By substituting in (1) T, total duration of blow, for t, and calling the resulting value of c, $C\,m$, we have

$$C\,m = \frac{T^2}{a} \tag{3}$$

The work, W', that the constant force, R, equation (2), is capable of performing during the time T is

$$W' = R\,C\,m \tag{4}$$

The actual work, W, done during the time, T, by the resistance of specimen is

$$W = \frac{M\,V^2}{2} \tag{5}$$

It was *observed* that the values of W'—obtained from the different negatives by causing a parabola to pass through three consecutive points near the vertex of the impact curve, and substituting in (4) the value of a, given by the equation of such a parabola—could, without sensible error, be assumed as equal to just twice W.

Substituting 2 W, or $M\,V^2$, for W' in (4) and the value of $C\,m$ given by (2) and (3), we have

$$R = \frac{\sqrt{2}\,M\,V}{T} \tag{6}$$

For values of T between 0·003 and 0·004 second, and for specimens of pure annealed copper, subjected to compressive stresses, we may substitute, then, $\sqrt{2}$ for the coefficient, A, in the general formula,

$$R = \frac{A\,M\,V}{T}$$

In the report referred to, Ordnance Construction Note No. 71, it is shown that the limiting values of A are 1·57 + and unity. For such a slowly changing function, a few points, determined just as one point has been determined for copper by this investigation, will permit the accurate construction of curves showing, for different materials, the values of A as a function of T.

With tables constructed from these curves, it will be necessary, in testing a given specimen, to measure only the value of T. A table will give the value of A, the known mass and height of fall of striking weight will give the product $M\,V$, and the maximum resistance, R, can be stated shortly after delivery of blow. An impact curve will not be necessary in practical testing, since micrometer measurements before and after the blow will show the effect on specimen. The apparatus herein described will then be simplified and will become a chronograph pure and simple. The interval of time to be measured, *T*, is readily connected with the making and breaking of an electric current. With the striking weight as one pole, and the specimen, or piston resting on it, as another, the current will be made at the instant of impact and broken by rebound.

The foundation for any accurate chronograph must be a refined time scale, such as had to be provided for this investigation. As soon as this time scale was obtained, it was seen that a photochronograph for general use, especially in ordnance work, was available. It remained only to provide means for causing light signals to mark the beginning and the ending of the time interval to be measured. The simplest and most economical device for this purpose was the Ruhmkorf induction coil, and in 1891-92 a chronograph was designed by the writer and constructed by the Ordnance Department, U. S. Army, wherein the secondary sparks were photographed simultaneously with the time scale and gave the desired signals.

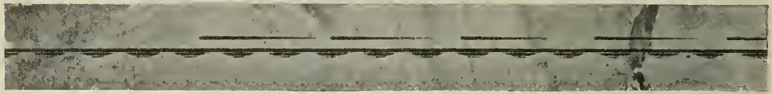

Fig. 15.

Fig. 15 is a reproduction of a record from this chronograph, which shows the times occupied by a projectile in passing over successive intervals of 2 feet.

A theoretical objection to the use of the Ruhmkorf coil is found in the fact that the secondary spark is not produced simultaneously with the break in primary circuit; but when we require *two successive* sparks and have a uniform time scale, even the slight errors due to this delayed action can be made to balance each other.

Fig. 16 reproduces another chronograph record, wherein the duration of secondary spark is made practically instantaneous and a fine shadow line is placed in each spark record. These shadow lines are of great assistance in obtaining accurate measurements from the photographs.

Some years after the construction of this photochronograph, two other investigators, working independently of the writer, produced an instrument involving a new method of securing the light signals.*

This highly ingenious and original method reduces materially the delayed action above mentioned, but it does not seem possible to procure with it the well-defined limits for use in measuring, given by shadow lines in spark records, *Fig. 16.*

With chronographs available for measuring T with the required accuracy, the outlook for a practicable and a reliable "Impact Testing Machine" seems promising.

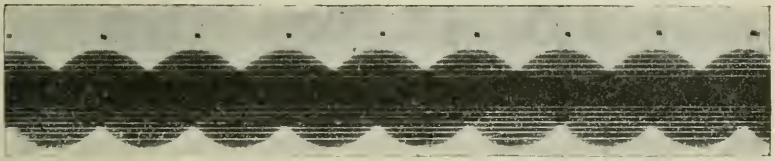

FIG. 16.

One other possible simplification remains to be mentioned. It will be remarked that in the general formula for R,

$$R = A \frac{M V}{T}$$

the second factor expresses the *mean resistance* of specimen. Another expression for this mean resistance is obtained by dividing the *energy* in striking mass by the *path.*

It may be found more convenient and more expeditious to measure the *path* rather than the *time.* In this case it will be necessary to determine A as a function of the height of fall of striking mass. This may or may not be possible. If so, the use of photography, and the consequent complications and delays—due to necessity for operating in a dark room, to time required for development, etc.—may be avoided.

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* See article on "Polarizing Photo-Chronograph," by Doctor Crehore and Lieutenant Squier, U. S. Army, in *Journal of the United States Artillery,* Vol. VI, No. 3.

CONCLUSION.

The measurement of intensities of impulsive forces is of general interest to the scientific world and of special interest to the engineering profession.

It is suggested that in some thoroughly equipped laboratory an extension of the investigation herein described should be made.

AN ATTEMPT AT A SYNTHETICAL DEMONSTRATION OF THE PRIMARY PROBLEMS OF THE DIFFERENTIAL CALCULUS.

BY DAVID WALTER BROWN, PH.D.

I attempt in the following paper to demonstrate the primary problems of the differential calculus by a method of direct synthetical reasoning, as distinguished from the somewhat indirect method of infinitesimals and limiting ratios. The demonstration proceeds upon the application of simple laws of proportion to variable quantities.

In the discussion the usual sign $\int$ for a function is retained. The meaning of the new signs for the *rate of change*, the *rate-ratio*, and the *variable multiplier* will be explained in the proper place.

A *variable quantity* (or simply, *variable*) is one whose magnitude changes; a *constant quantity* (or simply, *constant*) is one whose magnitude does not change.

I designate the rapidity of the change of a quantity by the term *rate of change* (or more simply, *change-rate*), and indicate it by the letter C (which is the initial of "change") written before the symbol for the quantity.

Thus $C\ x$ signifies the change-rate of x; $C\ y$ the change-rate of y, and so on.

When the hypothesis assumes that the change-rate of a variable does not depend upon the change-rate of any other quantity, then the variable is called *an independent variable.* When the change-rate of the variable depends upon the change-rate of some other quantity, the variable is called a *function* of that other quantity.

Properly speaking, the *change-rate* is not a quantity, although it has commensurable magnitude. It is only a property of a quantity, analogous to the velocity of a moving body, and similar to the fluxion of Sir Isaac Newton. I think the change-rate of a quantity can no more be considered a quantity, in the sense its variable is a quantity, than the color or velocity of a body can be considered the body to which it pertains.

The magnitude of the change-rate is not arbitrary in any problem. It is fixed once for all by the hypothesis of the problem itself, and can not be increased or decreased in the discussion of that problem. Its magnitude, moreover, is not dependent upon the instantaneous magnitude of its variable, but may be many times greater than the magnitude of the variable. In those cases where the magnitude of the change-rate is a constant, as hypothesis assumes it to be in the case of independent variables, the change-rate remains unchanged through all the changes of the variable, and is the same when the magnitude of the variable is zero as when it is infinitely great.

In considering the proportional effect produced upon the magnitude of a function by the changing magnitude of a variable, it becomes evident that this effect can not be due solely and entirely to the magnitude of the change-rate of the variable, but is due to the proportion which the magnitude of the change-rate bears to the simultaneous magnitude of the variable, since this proportion expresses the proportion or ratio in which the magnitude of the variable is changing under the influence of the change-rate, and that the development of this proportion must influence the development of the proportional change of the magnitude of the function.

I term this ratio of the magnitude of the change-rate to the simultaneous magnitude of its variable, the *rate-ratio*, and indicate it by the letter R written before the variable. Thus $R\,x$ signifies the rate-ratio of x; $R\,y$ the rate-ratio of y, etc.

Since the rate-ratio of a variable is the proportion which the magnitude of the change-rate bears to the simultaneous magnitude of its variable, the rate-ratio is equal to the quotient obtained by dividing the magnitude of the change-rate by the simultaneous magnitude of the variable. Or, since the symbols for the variable, the function, and the change-rate convey to the mind the notion of instantaneous magnitude, we may say more briefly and simply, the rate-ratio is the quotient of the change-rate divided by its variable. Therefore, in a similar manner we may say that the change-rate is the product of the rate-ratio multiplied by its variable, and the variable is the quotient of the change-rate divided by the rate-ratio.

Or in symbols

$$R\,x = \frac{C\,x}{x} \tag{1}$$

$$C\,x = (R\,x)\,x \tag{2}$$

$$x = \frac{C\,x}{R\,x} \tag{3*}$$

Since the rate-ratio is the proportion at which, at any instant, the magnitude of a variable quantity is changing, and since this proportion is equal to the magnitude of the change-rate divided by the simultaneous magnitude of the variable, the rate-ratio of any variable quantity goes through a development which depends upon the changing proportion between the simultaneous magnitudes of the change-rate and its variable. In the case of a constant change-rate the law of the development of the rate-ratio follows the changes of the magnitude of the quotient of a constant quantity divided by a variable quantity whose magnitude is changing according to an arithmetical series. In those cases, however, when the change-rate is variable, the law of development of the rate-ratio follows the change of magnitude of a fraction whose numerator and denominator are both changing according to certain laws. Generally, however, in determining the primary laws of the calculus, we are relieved from particularly considering the law of development of the rate-ratio. We only observe the instantaneous value of the ratio, and mentally make a note of the fact that it is developing according to some law, whatever that law may be.

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*Equation 3 is a general equation of integration.

We also observe that the expression for the magnitude of the rate-ratio,

$$\frac{C\,x}{x}$$

is universal, since it clearly allows for any development of the change-rate, or of the variable, or of both.

THE MEANING OF EQUALITY IN THE CALCULUS.

In general, when our hypothesis leads us to assume that any two quantities are equal, in reasoning on the calculus, the idea of equality has a two-fold significance: (1) that the magnitudes of the two quantities are equal at the instant of our observation; (2) that they remain equal throughout the entire development of those quantities. Thus, if we express such an hypothesis by the symbols $x=y$, we perceive that this equation signifies both that x and y are equal at the instant of our observation, and that they remain equal throughout their entire development. And this proposition is universally true, when comparing variables, functions, and the ratios of variables and functions. Thus, if we have the equality expressed by the symbols

$$\int z = \int x;\ y = a\,x;\ xy = z;\ x : y = s$$

etc., in every case the relation of equality continues throughout the entire development of the variable, or function, or ratio in question, and we perceive that the equality of constant quantities is but a special case of the general law.

In the reasoning of the calculus there is but one exception, if it be an exception, viz.: that after the analysis of the relations of the change-rate has been completed we may, in order to ascertain the momentary values of equations, make the variable equal to some constant quantity. But in this case we are no longer dealing with the laws of development of the change-rate, but only with the momentary effect produced by those laws.

Let us now examine some of the consequences of this law of equality. Suppose we are considering the case where a variable is equal to the product of some other variable by a constant, expressed in symbols by

$$y = a\,x$$

This immediately gives us the proportion

$$1 : a :: x : y$$

But since the ratio $1 : a$ is a *constant* by hypothesis, the ratio $x : y$ must also be a *constant*, ever equal to the ratio $1 : a$. But this is only possible when x and y are simultaneously increasing or decreasing in the same proportion of their own simultaneous magnitudes, and when the increase or decrease of both follows the same law of development. For, in any other case, the ratio of the magnitude of x to the simultaneous magnitude of y would change during the development of the two quantities.

It therefore follows that the rate-ratio of y is the same as the rate-ratio of x, and we perceive the truth of this principle of the calculus:

I. The rate-ratio of the product of a variable by a constant is the same as the rate-ratio of the variable.

Expressed in symbols,

$$R\,y = R\,a\,x = R\,x = \frac{C\,x}{x} \tag{4}$$

Since the change-rate of y equals the rate-ratio thereof multiplied by y, we have

$$C\,y = y\,(R\,y) = y\left(\frac{C\,x}{x}\right) = a\ x\left(\frac{C\,x}{x}\right) = a\ C\,x \tag{5}$$

and we have established this proposition:

II. The change-rate of the product of a variable by a constant is equal to the change-rate of the variable multiplied by the constant.

Evidently we may now assume that any variable is the product of a constant whose magnitude is equal to the simultaneous magnitude of its variable, multiplied by a variable whose original magnitude is unity, and whose rate-ratio is the same as the rate-ratio of the first named variable. I indicate this unity variable by the sign for unity (1) with the symbol of the variable out of which it is derived in each case written as a sub-index. Thus we may write $x = a\ (1_x)$, where $a = x$.

and the symbol (1_x) indicates a variable whose magnitude, at the instant of our observation, is unity, and whose rate-ratio is the same as that of x. Similarly we may write

$$y = b\,(1_y);\ z = c\,(1_z),\ \text{etc.}$$

But the magnitude of the change-rate of (1_x) is equal to the magnitude of the rate-ratio multiplied by the simultaneous magnitude of the variable, and, therefore, the change-rate of (1_x) is equal to the rate-ratio thereof multiplied by unity. Consequently the rate-ratio and the change-rate of the unity variable are equal each to each.

In symbols

$$C\,(1_x) = 1 \,.\, R\,(1_x) = \frac{C\,x}{x}$$

I call this unity (1_x) variable the *variable multiplier,* because it is the variable multiplier of the constant factor of the variable whose effects on a function we are considering. Certain of the conditions which arise in the discussion of the relations of the rate ratios of variables are more clearly explained by resorting to the use of it, than in any other manner.

Consider next the ratio of two quantities, and first of constants of equal magnitude. Evidently that ratio is unity and a constant. In symbols $a : a = 1$.

Consider next the ratio of a constant to a variable, which has momentarily the same magnitude as the constant. Evidently the momentary value of the ratio is unity, but the ratio is not now a constant.

Expressed in symbols the ratio is

$$a : x$$

We can put $x = a\,(1_x)$, and the ratio may be expressed

$$a : a\,(1_x)$$

Assume we started with two constants, *a, a,* the ratio having been

$$a : a = 1$$

Manifestly we have multiplied the consequent by the variable (1_x), and since the antecedent remains unchanged, the ratio must be multiplied by the same variable, becoming $1\,(1_x)$, and we perceive at once that the ratio is now a variable, and has the same rate-ratio as x.

The same principle would also immediately appear upon considering the fraction

$$\frac{x}{a} \text{ or } \frac{a\ (1_x)}{a}$$

It is then axiomatic that the magnitude of the fraction is increasing in the same proportion of itself as the numerator is simultaneously increasing in a proportion of itself, and that the rate-ratio of the fraction must follow the same law of development as the rate-ratio of the numerator. Also, since the rate-ratio of a variable multiplied by a constant is the same as the rate-ratio of x, the rate-ratio of

$$\frac{b}{a}x$$

must be equal to the rate-ratio of x, and therefore the foregoing principles are universal, and we perceive these two propositions to be true:

III. The ratio of a constant to a variable has the same rate-ratio as the variable.

IV. The rate-ratio of a variable divided by a constant is the same as the rate-ratio of the variable.

Proposition IV also follows from proposition I. For if a variable is equal to the quotient of another variable divided by a constant, then the second variable must be equal to the product of the first variable multiplied by the constant, and this is the case of proposition I. Or in symbols, if

$$x = \frac{y}{a}$$

then must $y = a\,x$, and by proposition I, $R\,y = R\,x$.

But the change-rate is equal to the rate-ratio multiplied by its variable. Therefore, in symbols, for brevity, if

$$x = \frac{y}{a}, \text{ and } R\,x = R\,y$$

then $$C\,x = (R\,x)\,x = (R\,y)\frac{y}{a} = \left(\frac{C\,y}{y}\right).\frac{y}{a} = \frac{C\,y}{a} \qquad (6)$$

and we have established this proposition:

V. The change-rate of the quotient of a variable divided by a constant, is equal to the quotient obtained by dividing the change-rate by the constant.

Consider now the case of the quotient of two variables which are originally equal and have equal rate-ratios, that is, are each simultaneously increasing in the same proportion of their contemporaneous magnitudes. This quotient is manifestly unity and a constant. Or, in symbols,

$$\frac{x}{x} = 1$$

Now, suppose that, without changing its instantaneous magnitude, we increase the rate-ratio of the numerator of this fraction, by causing the numerator to increase in a greater ratio of its own magnitude than before; or, in other words of equivalent meaning, suppose that, without changing the instantaneous magnitude of the numerator, we cause it to increase more rapidly than before, by adding to its original rate-ratio some additional ratio. Evidently the numerator, with this new development of its rate-ratio, is increasing more rapidly than before, and evidently also, from the assumed conditions of its new increase, its magnitude, under the influence of the new ratio, is outstripping the simultaneous development of its old magnitude, as that proceeded under the old ratio, in exactly the ratio which was added to the old ratio. That is to say, the ratio between the simultaneous values of its old and its new magnitudes has now become a variable, instantaneously equal to unity, and increasing in the proportion of the added ratio. But the magnitude of the denominator of the fraction is, by hypothesis, equal to the original magnitude of the numerator, and the denominator also has the same rate-ratio as the numerator originally had. Therefore the magnitude of the numerator, with its new development, is outstripping the simultaneous magnitude of the denominator in exactly the same proportion as we have seen it is outstripping the development of its old magnitude as produced by its original rate-ratio. Therefore, the fraction

$$\frac{x'}{x}$$

has now become a variable; — x' representing the new development of the numerator—and we may write

$$\frac{x'}{x} = z$$

where the instantaneous magnitude of z is unity, and its rate-ratio is that which was added to the original development of the numerator. It follows, therefore, that the present rate-ratio of the numerator is equal to the original rate-ratio thereof (which is by hypothesis the same as the rate-ratio of the denominator) plus the rate-ratio of z. Or in symbols

$$R\,x' = R\,x + R\,z \tag{7}$$

But the equation

$$\frac{x'}{x} = z$$

gives us $x' = z\,x$, and we perceive that, in this case, the rate-ratio of x' is equal to the sum of the rate-ratios of the two variables of which x' is the product. Therefore this proposition is true:

When the magnitude of a variable is instantaneously equal to unity, the rate-ratio of the product of that variable by another variable is the sum of the rate-ratios of the variables taken separately.

But since we know, from proposition I, that the rate-ratio of any product of a variable by a constant is the same as the rate-ratio of the variable, so that we have

$$R\,(a\,x) = R\,x;\; R\,(b\,x') = R\,x';\; R\,(c\,z) = R\,z$$

whatever the magnitudes of the constants may be, we perceive the foregoing principle to be universal, and we arrive at this proposition:

VI. The rate-ratio of the product of two variables is the sum of the rate-ratios of those variables taken separately.

In symbols we have, when $z = x\,y$,

$$R\,z = R\,x + R\,y \tag{8}$$

Therefore

$$C\,z = (R\,z)\,z = (R\,x + R\,y)\,x\,y$$

and

$$C\,z = \left(\frac{C\,x}{x} + \frac{C\,y}{y}\right)x\,y = y\,C\,x + x\,C\,y \tag{9}$$

That is to say:

VII. The change-rate of the product of two variables is equal to the sum of the products of each variable by the change-rate of the other.

For the case of x^2, where x and y become equal, this resolves to

$$x\,C\,x + x\,C\,x = 2\,x\,C\,x \tag{10}$$

Suppose we have to consider the rate-ratio of the product of the three variables, x, y, z.

Plainly we may let the product of x by y be equal to s, and then we have

$$R\,(s\,z) = R\,s + R\,z$$

But

$$R\,s = R\,x + R\,y$$

so that finally we get

$$R\,(x\,.\,y\,.\,z) = R\,x + R\,y + R\,z \tag{11}$$

and we perceive the general law:

VIII. The rate-ratio of the product of any number of variables is the sum of the rate-ratios of those variables taken separately.

Suppose $s = x, y, z$

Then

$$R\,s = R\,x + R\,y + R\,z$$

and

$$C\,s = \left(\frac{C\,x}{x} + \frac{C\,y}{y} + \frac{C\,z}{z}\right) x\,y\,z = y\,z\,C\,x + x\,z\,C\,y + x\,y\,C\,z \tag{12}$$

That is:

IX. The change-rate of the product of any number of variables is equal to the sum of the products obtained by multiplying the change-rate of each variable by all the other variables.

This leads directly to the proposition that

$$C\,x^{\mathrm{n}} = n\,x^{\mathrm{n}-1}\,C\,x \tag{13}$$

That is,

X. The change-rate of any power of a variable is equal to the product obtained by multiplying the change-rate by the variable raised to a power one less than its original power, and this product multiplied by the exponent of the power.

Consider next the ratio $x : a$.

Evidently if the antecedent is increasing in any proportion of itself, while the consequent remains constant, the ratio is decreasing in the same proportion of itself, and the proportionate change of the antecedent and of the ratio must follow the same law. But since the ratio is decreasing while the antecedent is increasing, the change of the ratio must be expressed as negative, and therefore we find in this case that the ratio is a variable quantity, changing in the same proportion as the antecedent, but negatively. Hence the rate-ratio of the ratio is $-\,R\,x$. But this is the same case as

$$\frac{a}{x}$$

and we perceive that—

XI. The rate-ratio of a constant quantity divided by a variable is the rate-ratio of the variable with the opposite sign.

In symbols,

$$R\left(\frac{a}{x}\right) = -\,R\,x \tag{14}$$

But,

$$C\left(\frac{a}{x}\right) = R\left(\frac{a}{x}\right)\frac{a}{x} = -\left(R\,x\right)\frac{a}{x} = -\,\frac{C\,x}{x}\cdot\frac{a}{x} = -\,\frac{a\,C\,x}{x^2} \tag{15}$$

That is,

XII. The change-rate of a constant divided by a variable at the first power is equal to the quotient obtained by dividing the product of the constant into the change-rate of the variable by the square of the variable, and this quotient having the opposite sign from that of the change-rate of the variable.

We could also deduce propositions XI and XII from proposition VI. For since $R\,x\,y = R\,x + R\,y$, then, when $x\,y = a$, we have $R\,x + R\,y = O$, whence $R\,x = -\,R\,y$, and consequently, if $R\,x$ be positive, $R\,y$ must have the same expression for magnitude, but with the negative sign.

But

$$C\left(\frac{a}{x}\right) = C\,y = (R\,y)\,y = (-\,R\,x)\,y\,. = -\,\frac{C\,x}{x}\cdot\frac{a}{x} = -\,\frac{a\,C\,x}{x^2}\,*$$

Let us next consider the case of a function which is equal to a variable plus a constant. Evidently the change-rate of such a function is solely and entirely due to the change-rate of the variable, and cannot be effected by the constant. Therefore the change-rate of such function must be the change-rate of the variable. Or, in symbols, if $y = a + x$, then $C\,y = C\,x$.

We reach the same conclusion from consideration of the rate-ratio of such a function. For, evidently, the rate-ratio thereof, that is the proportion of its own magnitude at which the function is changing, cannot now be the same as the rate-ratio of the variable, but must be to the rate-ratio of the variable in the inverse proportion of the magnitudes of the variable and the function. Or, in symbols,

$$R\,(a + x) : R\,x :: x : a + x$$

Whence we have

$$R\,(a + x) = \frac{(R\,x)\,x}{a + x} = \frac{C\,x}{a + x}$$

Consequently the change-rate of

$$a + x = R\,(a + x)\,.\,a + x$$

which equals

$$\left(\frac{C\,x}{a + x}\right)(a + x) = C\,x \qquad (16)$$

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* By a simple application of proposition VI, we shall find that the change-rate of the quotient of a constant divided by any power of a variable,

$$\left(\text{in symbols, } \frac{a}{x^{n}}\right)$$

is equal to the product of the change-rate of the variable into the constant, into the exponent of the power, divided by the variable raised to a power one greater than its original power, and this quotient having the minus sign. Or,

$$\left(\text{in symbols, } C\left(\frac{a}{x^{n}}\right) = -\,\frac{n\,a\,C\,x}{x^{\,n+1}}\right)$$

Similar reasoning proves that the change-rate of a variable less a constant is the same as the change-rate of the variable. Or, in symbols, $C\,(x - a) = C\,x$.

Thus we have established this proposition:

XIII. The change-rate of a variable increased or diminished by a constant is the same as the change-rate of the variable.

Let us next consider the case of the sum of two variables.

When the variables are such that one may be regarded as the function of the other, we may write $y = a\,x$. So that the sum of $x + y$ becomes $x\,(1 + a)$. But we know from previous principles that the rate-ratio of this quantity is equal to the rate-ratio of x. Let us express the relations in symbols,

$$R\,(x\,(1 + a) = R\,x$$

But the change-rate of a variable is equal to the rate-ratio thereof multiplied by the variable. That is,

$$C\,(x\,(1 + a) = R(x\,(1 + a)\,(x\,(1 + a) = R\,x(x\,(1 + a) =$$

$$\frac{C\,x}{x}\,(x(1 + a) = C\,x + a\,C\,x \qquad (17)$$

But since $y = a\,x$, $a\,C\,x$ is the change-rate of y, and we have:

XIV. The change-rate of the sum of two variables is the sum of the change-rates of the variables.

When, however, one of the variables is not a function of the other, the same law still holds true. For, in the case of the sum of two such variables, we observe we have the condition of the independent developments of the change-rates and the rate-ratios of two variables, each development unaffected by the other, and, as a necessary consequence, the total effect of the two developments must be the sum of the effects separately due to each. We thus have presented the case of a quantity made up of two independent parts, each of which is changing in some proportion of its own magnitude, unaffected by and unaffecting the change of the other part. In such circumstances, it is evident that the proportional change of the whole, due to the proportional change of either part, must be to the proportional change of that part in the inverse ratio of the magnitudes of the whole and the part. This gives us, as the expression for the proportional change of the whole, due to the proportional change of x,

$$R\,x\left(\frac{x}{x+y}\right)$$

and similarly as to y,

$$R\,y\left(\frac{y}{x+y}\right)$$

Therefore the rate-ratio of the whole is

$$R\,(x+y)=\frac{x\,(R\,x)+y\,(R\,y)}{x+y}$$

whence the change-rate of $x+y$ is found, thus

$$C(x+y)=R\,(x+y)(x+y)=\left(\frac{x\,(R\,x)+y\,(R\,y)}{x+y}\right)(x+y)= \\ C\,x+C\,y \qquad (18)$$

The foregoing principles enable us to determine expressions for the change-rate of any product, quotient, power or root of a variable, or of the sum or difference, product or quotient of any combination of variables, or of the power or root of such combination.

It is now manifest that the relations of the change-rate of a variable to the change-rate of its functions are the same as those commonly said to exist between the differential of a variable and the differentials of its functions. But the method of change-rates and rate-ratios here developed has a certain logical superiority over the method of the differential, as usually treated.

In the first place, the primary definition of the change of magnitude of a variable as due to a rate of change, which is analogous to the velocity of a moving body, is a definition which corresponds to the fact. The development of a variable quantity is comparable to a ceaseless flow, but it is not comparable to a broken step-by-step change, such as the usual method of infinitesimals necessarily assumes it to be.

Again the method of rates of change is logically consistent in defining the rate of change to be only a property of a quantity, possessing commensurable magnitude, but not itself a quantity—no more so than is the velocity of a moving body the body to which it pertains.

Finally, by insisting that the magnitude of the rate of change is not arbitrary in any problem, but is once for all fixed by the primary hypothesis of that problem, this method conforms the development of the variable through its functions to the well-known facts often presented in the concrete problems, particularly of engineering, to which the calculus is applied; in which it is logically impossible to suppose the magnitude of the rate of change to be other than the concrete conditions show it necessarily is.

The treatment of the development of a variable quantity as due to another quantity whose magnitude is arbitrary and may therefore be made infinitesimal, involves the logical fallacy that since we are unable to derive the relations of the differential from the finite magnitude assigned to it by the hypothesis of our concrete problem, we may change that magnitude to an infinitesimal magnitude, and then, having reached a limiting ratio, for the case when the differential is infinitesimal, assume, without positive proof, that ratio holds true when the differential has the assigned finite magnitude, although the operations by which we arrive at the limiting ratio cannot be performed in the case when the differential has a finite magnitude. The mind may accept the conclusion, but it objects to the logic of the method.

The method of the change-rate is a return to the conception of the great inventor of fluxions, and avoids the logical difficulties which inhere in the treatment of the differential as an arbitrary quantity.

THE MAXIMA AND MINIMA OF FUNCTIONS.

It has been my purpose to demonstrate the primary problems of the differential calculus, not to apply the solutions of those problems.

But the harmony of the conceptions of the change-rate and the rate-ratio with the elementary conditions of the maxima and minima of functions deserves notice.

At the instant of the maximum or minimum of a function, the differential of the function is said to be zero.

But since a differential is an infinitesimal quantity, by the usual hypothesis, and smaller than any assignable magnitude, it is not easy, upon merely logical grounds, to perceive why, at the instant of the maximum or minimum of the function, its differential need be any smaller than it always has been, nor why the limit of this quantity should not just coincide with the maximum or minimum; and the statement that the magnitude of the differential is zero at the minimum or maximum therefore becomes unnecessary and without significance.

But again, in concrete problems connected with areas of curves and like subjects, the differential is assumed to be an infinitely thin strip or lamina of the surface or solid under consideration. But if this be so, then upon no logical grounds whatever can it be shown that the division between two adjacent laminæ does not occur exactly at the minimum or maximum; but if the division between two adjacent laminæ does occur at the maximum or minimum, then there is no greater propriety in saying that the differential is zero at those points, than in saying it is zero at the indefinite number of other points where such a division occurs.

But when we once perceive that the variation of the magnitude of a function is due to a change-rate, and that if, as the function is approaching the maximum, its change-rate is positive, because it is then increasing the magnitude of the function, and if, as the function passes the maximum, its change-rate becomes negative, because it is then decreasing the magnitude of the function, it follows as a necessity of logical thinking that a positive rate can become a negative rate only by becoming zero at the instant of its change from positive to negative, and the principle becomes axiomatic that—

At the maximum or minimum of a function its change-rate is zero.

Now, the rate-ratio offers us the means of determining whether a given value for a variable, deduced by making the change-rate of the function zero, is a maximum or a minimum; for, *When a function is passing through the maximum, the sign of its rate-ratio changes to the opposite sign from that of the function; and when the function is passing through the minimum the sign of its rate-ratio changes to the same sign as that of the function.*

This proposition is deduced from the following considerations:

At the instant of the maximum, the function has a certain magnitude (assume it to be positive). As the function passes the maximum, its magnitude cannot at once pass from positive to negative, nor can it become instantly equal to zero. For the law of the development of every variable and function is that of ceaseless, unbroken flow, which is inconsistent with either of the foregoing suppositions.

Therefore, for a certain range of development beyond the maximum, the function remains positive, but its change-rate has become negative at the instant of passing through the maximum. Therefore the rate-ratio, which is the quotient of the change-rate divided by the function, became negative as the function passed through the maximum.

For the case of the minimum, suppose the function to have a positive value, but the least possible: Upon the grounds above stated, and yet more clearly, the function remains positive as it passes the minimum. But the change-rate became positive at the instant of passing through the minimum, and therefore the sign of the rate-ratio became positive as the function passed through the minimum.

If the function is considered negative at the instant of the minimum, it will be found that the rate-ratio will become negative as the function passes through the minimum, and conversely in the case of passing through the maximum.

To apply the foregoing principles to simple cases. Suppose we are required to divide a line into two such parts that the rectangle erected on the parts of the line shall be a maximum. If the line be a, and x be one part, $a - x$ will be the other part, and $a\,x - x^2$ will be the rectangle. Since this is to be a maximum, we have

$$C\,(a\,x - x^2) = o$$

whence

$$a\,C x - 2\,x\,C x = 0$$

and

$$a = 2\,x$$

whence

$$a = \frac{1}{2}\,x$$

Now construct the rate-ratio,

$$R(a\,x - x^2) = \frac{C(a\,x - x^2)}{a\,x - x^2} = \frac{C\,x\,(a - 2\,x)}{a\,x - x^2}$$

Observation shows us:

That the magnitude of the denominator remains positive even when x becomes greater than

$$\frac{1}{2}\,a$$

but that the numerator becomes negative when x increases beyond

$$\frac{1}{2}\,a$$

because then $a - 2\,x$ becomes negative. Therefore, as the function passes the value assigned to it when

$$x = \frac{1}{2}\,a$$

the sign of the rate-ratio becomes negative, and we know that the value

$$x = \frac{1}{2}\,a$$

gives a maximum value to the function.

Suppose we have a given area h, which is to be arranged into a rectangle such that the perimeter shall be a minimum.

If one side of the rectangle is x, the adjacent side is

$$\frac{h}{x}$$

and the perimeter becomes

$$2x + \frac{2h}{x}$$

But since this is to be a minimum, we have

$$C\left(2x + \frac{2h}{x}\right) = o, \text{ whence } 2Cx - \frac{2hCx}{x^2} = O$$

Whence,

$$2x^2 - 2h = o, \text{ and } x = \sqrt{h}$$

Again construct the rate-ratio

$$\frac{Cx\left(\frac{2x^2 - 2h}{x^2}\right)}{\frac{2x^2 + 2h}{x}}$$

which is equal to

$$\frac{Cx(2x^2 - 2h)}{x(2x^2 + 2h)}$$

Observation shows us that when x becomes greater than $\sqrt{h}$, the numerator and the denominator of this fraction will both be positive, and we therefore know that the value $x = \sqrt{h}$ is that which makes the function a minimum.

NEW YORK, MARCH 13, 1897.

CHEMICAL SECTION.

(*Stated meeting, Tuesday, September 21, 1897.*)

DR. LEE K. FRANKEL, Vice-President, in the chair.

THE UPPER SCHUYLKILL RIVER.

BY OSCAR C. S. CARTER,
Professor of Geology and Mineralogy, Central High School, Philadelphia.

This river, which furnishes a water supply to Philadelphia and several towns along its banks, rises in the coal regions, in the northeastern part of Schuylkill County, Pa., nearly 100 miles from Philadelphia. It flows southwest, then changes to southeast, and then enters Berks County by a gap in the North Mountain at Port Clinton. It then flows southeast through the Great Limestone Valley and cuts through the South Mountain at the city of Reading. After leaving Berks County, it forms the boundary between Montgomery and Chester Counties, where it flows through the New Red Sandstone. It then enters the belt of older gneissic and micaceous rocks and flows southeast through Philadelphia County to the Delaware River.

Its general direction from the time it enters the gap in the North Mountain at Port Clinton until it enters the gap in the South Mountain at Reading is south 10° east; it then changes its course to south 50° east, being deflected by the spurs of the South Mountain and by meeting the New Red Sandstone. It continues in this general direction to Philadelphia.

Elevation above Tide.—The general elevation of the Schuylkill and its tributaries at their source in the coal regions is about 800 feet higher than Philadelphia at the mouth of the river. In fact, the elevation of some of the towns near its source in Schuylkill County is over 1,200 feet. Mahanoy City is 1,240 feet; Pottsville is 611 feet, and Tamaqua, near the Little Schuylkill River, is 800 feet. These elevations are above mean tide at Philadelphia. The measurements given by the Schuylkill Navigation Company show that the fall of the river is as follows:

From Pottsville to Port Clinton, a distance of 15 miles, the river descends 204 feet = 14 feet fall per mile.

From Port Clinton to Reading, a distance of 20 miles, the river descends 202 feet = 10 feet fall per mile.

From Reading to Norristown, a distance of 41 miles, the river descends 141 feet = 3½ feet per mile.

From Norristown to Philadelphia, a distance of 17 miles, the river descends 61 feet = 3½ feet fall per mile.

Acidity of the Schuylkill above Reading.—The Schuylkill River, above the city of Reading, is so strongly charged with sulphuric acid and sulphate of iron that it cannot be used as a water supply for Reading and the towns along its banks between Reading and the coal regions. We refer now to the Schuylkill, and do not include the Maiden and Tulpehocken Creeks, both of which empty into the river near Reading. Water of this kind would strongly corrode iron boilers, so that it cannot safely be used for the generation of steam. Its effect on the fauna of the Schuylkill is strongly marked. There are practically no fish in the river between Reading and Tamaqua, which is situated on the Little Schuylkill, or, more strictly speaking, between Maiden Creek, which is 8 miles above Reading and Tamaqua. A few suckers find their way above Reading as far as Maiden Creek, but above this no black bass, perch or chub are found. Molluscan life, which is provided with a protective shell of carbonate of lime, does not flourish in this acid water; their shells would be corroded and slowly dissolved. Mussels, water snails and cray fish find more congenial quarters in the Lower Schuylkill below Reading, where the water has lost its acidity.

It is well known that the acidity of the Schuylkill is due to impurities found in coal. Coal generally contains sulphur in two forms, as pyrite, or sulphide of iron (FeS_2), and sometimes as an organic compound of sulphur, which has not as yet been studied. When iron sulphide oxidizes on exposure to air, or water containing dissolved oxygen, it begins to disintegrate, and is finally converted into sulphuric acid and sulphate of iron, both of which are soluble in water. The pyrite is the principal source of sulphur in coal; in many specimens of coal and coaly slate, these glistening yellow specks are plainly visible. Every sample of coal analyzed contains some sulphur.

Acid Water from Collieries.—The following analyses were made by W. J. Williams, and show clearly the amount of free sulphuric acid and soluble sulphates that are found in water pumped from coal mines. The Lee Colliery is not on the Schuylkill Watershed. It is situated on the Susquehanna. Both of these waters, however, are typical mine waters of the Pennsylvania coal regions. The large amount of lime and magnesia sulphates in these waters is caused by the action of the free sulphuric acid on the rocks in and near the mines:

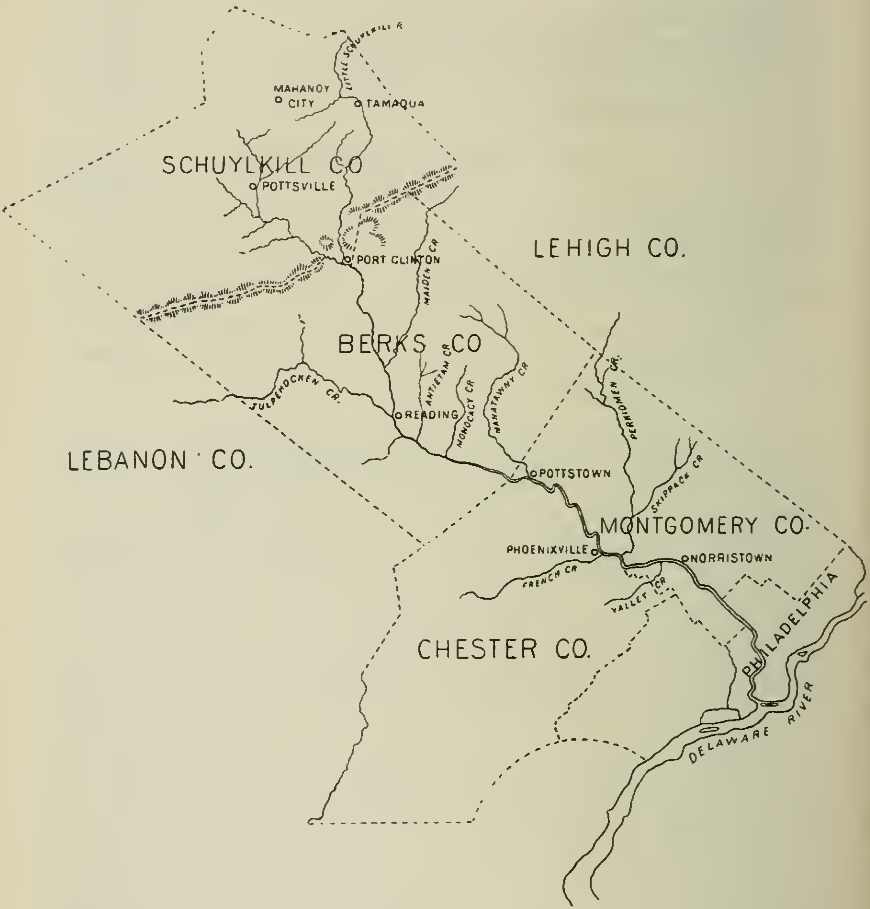
READING COAL AND IRON COMPANY. WATER FROM ELLEN GOWAN COLLIERY.

	Grains per U. S. Gallon.
Free sulphuric acid	19·60
Iron and aluminum sulphates	140·23
Calcium sulphate	45·75
Magnesium sulphate	39·72
Sodium chloride	4·68
Insoluble matter (principally coal dust)	5·04
Volatile and organic matter	43·00
Total solid matter	298·02

LEE COAL COMPANY, SCRANTON, PA.

	Grains per U. S. Gallon.
Free sulphuric acid	7·53
Iron sulphate	19·20
Calcium and magnesium sulphates	21·84
Sand	2·12
Volatile and organic matter	19·01
Sodium chloride	Traces
Total solid matter	69·70

The various tributaries of the Schuylkill River, in Schuylkill County, flow through the coal regions, and all the acid mine water which is pumped from the mines finds its way into the river. Years ago, before coal was mined in Pennsylvania, the river was free from acidity from its source to its mouth and fish were found along its entire course. It is stated that the amount of acid in the Big Schuylkill from Pottsville and beyond has been decreasing since 1868, owing to the transfer of mining operations to the other side of the mountains, where the streams drain into the Susquehanna, and that the amount of sulphuric acid in the Big Schuylkill in 1885 was only one-third of what it formerly was. This is probably true, but the writer has never been able to find any analyses on record by which a comparison of the amount of acid in the Upper Schuylkill could be made. While a great number of analyses have been made of the water in the Lower Schuylkill, but few, if any, complete analyses of the upper river are accessible. There seemed to be no necessity for such work, on account of its well-known unfitness for drinking purposes. The stream which furnishes the most sulphuric acid and sulphate of iron to the river is undoubtedly the Little Schuylkill. In the region of Tamaqua no fish can exist, and the stones in and along the river are colored brown from the precipitated iron in the form of ferric hydrate. On account of the decrease of acid in the Big Schuylkill beyond Pottsville a few hardy catfish have found their way up the river probably during some season of freshet when the water was strongly diluted and rendered comparatively fresh. A few of these fish are found between Port Clinton and Pottsville, but no others. These fish are not found in the river lower down between Port Clinton and



Reading, because the Little Schuylkill discharges its acid waters into the river at Port Clinton.

How the Acidity is Destroyed.—Those unacquainted with the Schuylkill might suppose that this strongly acid water from the coal regions might reach Philadelphia and affect the water supply. Such, however, is not the case. Even the towns of Phœnixville and Pottstown are unaffected by it in the slightest degree. The water loses its acid character in the vicinity of Reading, and a short distance below that city the neutralization is complete. This is due to the fact that two important streams of hard water, the Maiden and Tulpehocken Creeks, flow through the limestone country and empty into the river near and at the city of Reading. The carbonate of lime, which they hold in solution completely, neutralizes the sulphuric acid and sulphate of iron in the water. In this double decomposition which takes place, two precipitates are thrown down, namely, sulphate of lime and carbonate of iron. The reaction is as follows:

$$\begin{array}{l} CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + 2CO_2 \\ \quad CO_2 \end{array}$$

$$\begin{array}{l} CaCO_3 + FeSO_4 = CaSO_4 + FeCO_3 + CO_2. \\ \quad CO_2 \end{array}$$

The carbonate of iron being a very unstable salt, soon oxidizes to $Fe_2(OH)_6$, ferric hydrate, and this brown stain of iron rust is often seen on the dam at Reading when the water is low. From the bridge at Reading, when the water is not muddy or turbid from coal dust, this white precipitate of sulphate of lime can clearly be seen.

The Tulpehocken and Wyamissing empty their limestone water into the river near this point, and the precipitated sulphate of lime renders the water almost milky in appearance, especially when an excess of acid water has been pumped from the mines. This salt of lime is slightly soluble in water, and a certain amount is dissolved. This accounts for most of the sulphate of lime in Schuylkill water, which analyses show is always present between Philadelphia and Reading.

Limestone Streams Emptying into the Schuylkill.—The principal branches of the Schuylkill which flow through limestone districts and whose waters are more or less hard, are the Maiden, Tulpehocken, Wyamissing, Monocacy, Manatawny and Valley Creeks.

Maiden Creek is about 25 miles long. It rises in Lehigh County and flows over the formation known as Hudson River Shale and Utica Slate. It enters Berks County and flows over the same formation. It is fed from the slopes and foothills of the North Mountain. Finally, it reaches the Great Limestone Valley, through which it flows for a distance of 8 miles. Analysis shows that the temporary hardness is 7, and that it contains 4·08 grains of carbonate of lime per gallon. Calculation shows that every million gallons of water that flows over the bed of Maiden Creek contains 571 pounds of carbonate of lime in solution, which helps to neutralize the acidity of the main river. Then again, pebbles and particles of limestone dust, loosened by erosion, are carried by the current into the river and their action on the acid water is the same.

Tulpehocken Creek rises in Lebanon County and flows east through about 5 miles of the Great Limestone Valley. It enters Berks County and follows the limestone valley for another 5 miles, then leaves the valley and flows north and then east through the Hudson River Shale. It finally crosses the limestone valley again and empties into the Schuylkill at Reading. This creek flows through limestone for a distance of about 15 miles. When the geology of the river is well understood, it will be interesting to know why the Tulpehocken did not take a short cut and follow the limestone valley along its entire course instead of flowing north through the Hudson River Shale. It seems to go out of its natural course. Perhaps all of the valley was not eroded sufficiently deep at that time.

Wyamissing Creek is a small creek which flows through about 3 miles of the Great Limestone Valley and empties into the river at Reading.

Monocacy Creek is another small stream which flows through about 3 miles of limestone, and the rest of the way through shale and gneiss. It empties into the Schuylkill a short distance below Reading.

Manatawny Creek rises in the gneiss, and flows south through about 8 miles of limestone country; the rest of its course is through the New Red Sandstone. It empties into the river at Pottstown.

These are the limestone streams of the Upper Schuylkill, and were it not for them, the acid water would reach Philadelphia and affect our water supply. It is not likely that the limestone of the Plymouth and Chester Valleys, which crosses the river between Norristown and Conshohocken, would completely neutralize it, because the bed of the river is covered with mud. The Tulpehocken and Maiden Creeks furnish the greatest volume of limestone water and prevent the acid water from getting below Reading.

Fish Perish in 1882.—In order to prove that the water supply of towns along the Lower Schuylkill would be affected if this acid water from the mines were not neutralized, it is only necessary to remember the summer of 1882, when so many fish perished along the river. Between Reading and Pottstown hundreds of dead fish were observed floating in the river. Many were noticed as far south as Perkiomen Creek. The Philadelphia newspapers devoted columns to it, as it was feared the water supply of the city would be affected. The cause was due to the opening of several abandoned coal mines, and the excess of acid water was pumped into the river. This unusual supply was more than the limestone streams could neutralize during the low-water season, in consequence of which the acid water passed far below the city of Reading.

Water Supply of Reading.—On account of the acidity of the Schuylkill at Reading, that city has utilized Maiden and Antietam Creeks as a water supply. These creeks are not near the coal regions, and they furnish an abundant supply of water. The following analysis of the water of Maiden Creek, made by Prof. A. R. Leeds and furnished by the Mayor, will exhibit its purity:

	Parts in 100,000.	Grains per Gallon.
Free ammonia	0·002	0·0012
Albuminoid ammonia	0·0043	0·0025
Oxygen required to oxidize organic matter	0·101	0·058
Nitrites	0·007	0·004
Chlorine	0·35	0·20
Total hardness	8·50	4·96
Permanent hardness	1·50	0·88
Temporary hardness	7·00	4·08

The report states that the quantities of free and albuminoid ammonia and nitrites are so small as not to need comment. They indicate but little drainage contamination. The water is somewhat hard, the temporary hardness being greater than the permanent hardness, which shows more carbonate than sulphate of lime. The hardness, in fact, is mainly due to the carbonate of lime.

Antietam Creek.—The other source of Reading's water supply is a mountain stream, which empties into the Schuylkill, about 4 miles below Reading. It is formed by the union of three mountain streams that have their origin in the high granitic or gneissic hills of Alsace Township. Water draining hills of gneiss is always soft. At the junction of these three mountain streams a reservoir was built, known as Antietam or Ohlinger Lake. The water is piped from the lake to Reading, a distance of about 3¾ miles. There are also two large springs which flow directly into the pipes; they are known as Hampden and Edelman Springs. The water of Antietam Lake was analyzed in 1896, by Prof. Leeds, with the following results:

	Parts in 100,000.	Grains per Gallon.
Free ammonia	0·005	0·0029
Albuminoid ammonia	0·042	0·025
Oxygen required to oxidize organic matter	0·449	0·26
Nitrites	0·008	0·0005
Chlorine	0·20	0·12

He states: "The albuminoid ammonia is ten times greater than that contained in the samples from Maiden Creek, and several times greater than is ever found in water of unquestionable purity. It amounts to the enormous figure of 0·042 parts per 100,000, and points to the presence of much matter derived from the drainage of manurial and sewage material into the water of the lake."

Bacteriological Investigation.—Prof. Leeds' remarks and the analyses of Reading's water supply are interesting as well as instructive, and it may not be amiss to quote them, as they contain some facts of general interest.

"The first step was to count the entire number of colonies of bacteria of all kinds contained in each sample of water.

COLONIES OF BACTERIA PER CUBIC CENTIMETER.

	Colonies.
South side of Maiden Creek	550
North side of Maiden Creek	440
Intake of Antietam Lake	1,200

"These figures tell us the number of bacteria, but nothing as to their nature, nor do they conclusively point to the presence of dangerous contamination. But it may be said that, as a general rule, surface waters which are entirely satisfactory contain from about 50 to 200 colonies of bacteria per cubic centimeter. When examined in March, 1894, the sample from Maiden Creek contained 50 colonies. At this present date, 1896, both samples contain a larger number of bacteria from Maiden Creek than was expected, judging from the results in 1894 and from the analysis of the water; but later on I shall show that these large numbers have not the damaging significance as at the first glance they appear to have. The mere counting of the relative numbers of bacteria in equal volumes of the water is a simple task compared with that of determining the species to which these multitudes of bacteria belong, and whether any of these species belong to the disease-producing varieties, the so-called pathogenic bacteria.

"In the present instance I was more especially charged to look for and report upon the presence or absence of the bacillus of typhoid fever in each of the four waters. To ascertain these facts a large number of cultures and hundreds of microscopic examinations, prosecuted without cessation and extending over the past interval of ten days, had to be made. The sample from the north side of Maiden Creek contained the fewest species. They belonged almost entirely to the kinds of bacteria which are always found in natural running waters. When water comes from very deep wells, it should contain very few or no bacteria, since these will have been filtered out by the subsoil before the water has found its way into the subterranean reservoir. But when water passes over the surface of the ground, it always takes up some organic matter and along with it some bacteria. These ordinary water bacteria in this case are essential and beneficial, because their work is to assist in the oxidation of the organic matter, and in this manner to purify the water. This was the work the species found in the water taken from the north side of Maiden Creek were doing, and although their number was large, I do not consider their presence prejudicial to the purity of this water. There were no pathogenic bacteria in samples taken from both the north and south sides of the creek, and I consider the supply from this source safe. The case is entirely different with the Antietam Lake and the faucet water. In both, but more especially the former, the bacteria belonging to species which are associated with decaying animal matters were those chiefly found. Most diligent search was made in both waters for the specific bacillus of typhoid fever (the bacillus typhi abdominalis or the bacillus of Eberth-Gaffky), which permeates the intestines and other organs of a typhoid patient, and after leaving the human body is capable of living a considerable time in the water contaminated by the voidings of the invalid. But this specific bacillus was not present in the two samples submitted to me. There were other bacilli present which are almost always associated with the typhoid bacillus, and which have, indeed, been called pseudo-typhoid bacilli, and it has been held by some eminent authorities that when these latter find their way into the alimentary tract, they take on increased virulence under favorable conditions and develop into the true bacillus of typhoid. However that may be, I consider the number and kinds of bacteria found in the Antietam Lake and faucet waters, more especially in connection with the corresponding evidence of the chemical analyses, sufficient to indicate that these waters were dangerously contaminated with bacteria capable of producing disease. In the light of the chemical and bacteriological investigations it was recommended that the work of excluding from the drainage area of Antietam Lake all matters of a sewage nature by means of condemnation and purchase of offending properties when necessary, or prohibition wherever mere prohibition would be effectual, should be pushed with great energy. The rights of the municipality in defending the purity of its water supply are paramount, and the legal remedies are adequate to meet every exigency." These recommendations were afterward carried out by the city and the source of contamination done away with and properties purchased.

Maiden Creek Pumping Station.—At this station they use two Worthington pumps, one 5,000,000 gallons and the other and newer 10,000,000 gallons. The water is pumped directly from the creek, 8 miles above Reading, and carried south to Hampden District reservoir, through 11,687 feet of 30-inch pipe and 22,105 feet of 24-inch pipe, against a static head of 208 feet. While it is possible to force 10,000,000 gallons daily through this main, it is considered safer to force 8,000,000 gallons.

STORAGE CAPACITY OF RESERVOIRS.

	Gallons.
Antietam Lake (Ohlinger), storage capacity	100,000,000
Bernhart Reservoir, " "	40,000,000
City Reservoirs, Penn Street, " "	6,200,000
Hampden Reservoir, " "	35,000,000
Egelman Reservoir, " "	2,000,000
Buttonwood Street Reservoir, " "	1,200,000
Total storage capacity	184,400,000

THE DAILY MAXIMUM CAPACITY OF STREAMS SUPPLYING THE CITY BY GRAVITY IN A DRY SEASON.

	Gallons.
Antietam Lake	2,000,000
Bernhart Reservoir	1,368,575
Hampden Springs	80,000
Egelman Springs	100,000
Hampden Drift	16,000
	3,564,575

The daily per capita consumption is about 120 gallons.

Water Supply of Towns below Reading.—The towns between Reading and Philadelphia obtain their water supply from the Schuylkill River. Pottstown formerly pumped from the river below the town, and thus received some surface drainage from the town. This was afterward changed, and the supply is now drawn from above the town. The reservoir is about 1 mile from the river, and has a capacity of 6,000,000 gallons. They have a pump that furnishes 4,500,000 gallons in twenty-four hours. Norristown also obtains a supply from the Schuylkill. There is an island in the river at that point over a mile in length, which divides the river in two parts. The water pipes run under the river and also the island, so that the supply is drawn from the other side of the island, thus avoiding the contamination of Stony Creek, which contains the drainage of the State Insane Asylum. The capacity of the reservoir is 11,000,000 gallons. They have two pumps, a Worthington, which supplies 5,000,000, and a Newbold, which supplies 2,500,000 gallons. The water between Reading and Norristown, a distance of 41 miles, is good as a general rule, because there are few towns between these points; the only two of considerable size are Pottstown and Phœnixville. The amount of drainage that gets into the river between these points can, to a certain extent, be regulated. Between Norristown and Philadelphia, as is well known, the water is not so pure, on account of drainage. It is not necessary to enlarge on this point, as the Lower Schuylkill has been well studied and many analyses have been made.

Fish of the Schuylkill.—The fish commissioners tell us that thirty-three years ago there were no black bass in Pennsylvania. At Harper's Ferry, on the Potomac, were purchased 450 full-sized adult bass; these were deposited in the Delaware near Easton. The writer remembers in 1870, when black bass were first introduced into the Schuylkill; in a few years they became quite abundant and of some importance as a food supply. At that time the red fin, roach and chub were abundant in the river, and the so-called dogfish was common. Many fishermen and some of the fish commissioners have informed me that the red fin is now extinct and the roach and chub are disappearing. The black bass feed on them. There are many German carp in parts of the Perkiomen and Skippack Creeks; in some places they keep the dams muddy. Among Americans this fish is not regarded with much favor, although it is a favorite food fish in Bohemia. The Delaware, at Trenton, is full of large carp. Near Burlington the carp fisheries furnish Philadelphia and Trenton with nearly a ton of carp per week, consumed mostly by foreigners. The black bass are decreasing in the Schuylkill, owing to the fact that the carp eat their spawn, and also to the fact that the culm or coal dust which comes from the coal region annoys them, as they do not thrive on muddy bottoms. Often after a heavy rain in the coal regions Philadelphia water will be dirty for a week. The greatest amount comes from the Little Schuylkill, although much is dumped along the Big Schuylkill. There was some coal dust dumped along the west side of the Schuylkill between Norristown and Philadelphia which the high water and heavy rains would stir up, but this practice has been stopped.

DR. JOSEPH W. RICHARDS, President, in the chair.

SOME NEW DERIVATIVES OF DIACETYL.

BY HARRY F. KELLER AND PHILIP MAAS.

Since communicating the results obtained in studying the action of oxidizing agents upon diacetyl, we have continued our work on this diketone in several directions.

The ready and quantitative conversion of diacetyl into acetic acid by certain oxidizing agents, notably hydrogen peroxide, induced us to try whether the halogen-substituted products, dibromo-diacetyl and tetrabromo-diacetyl, would behave in an analogous manner. If they, respectively, yielded bromacetic acid and dibromacetic acid, their symmetrical structure might be regarded as definitely established. Thus:

$$CH_2BrCO{\cdot}COCH_2Br + HO{\cdot}OH = 2CH_2Br{\cdot}COOH$$

and

$$CHBr_2CO{\cdot}COCHBr_2 + HO{\cdot}OH = 2CHBr_2{\cdot}COOH$$

While both compounds were found to be readily attacked by the oxidizing agent, only the dibromo-derivative gave something like the expected result.

A weighed quantity of this substance was treated in the cold with a moderate excess of hydrogen peroxide solution. The greasy scales gradually disappeared, and the liquid became strongly acid. Upon evaporating, it gave off hydrobromic acid, and left a residue consisting of a mixture of *bromacetic* and *glycollic* (oxyacetic) acids. This mixture was completely converted into the latter acid by prolonged boiling with water, according to the equation:

$$CH_2Br{\cdot}COOH + H_2O = CH_2(OH){\cdot}COOH + HBr.$$

The characteristic calcium salt was prepared. It was obtained in stellar aggregations of needles, having a silky luster, insoluble in alcohol and only sparingly soluble in cold water. It contained:

	I.	II.	Calculated for $(C_2\,H_3\,O_3)_2\,Ca + 4H^2O$.
Ca	15·06	15·54	15·26
H_2O	26·97	26·47	27·48

The salt is understood to be somewhat efflorescent, and the percentage of water therefore a little too low. The dehydrated salt gave Ca = 21.32 per cent., instead of 21·05 per cent., required by theory.

The blue copper salt was also obtained.

A mixture of several acids is produced when dibromodiacetyl is heated with nitric acid. We have not been able to effect their separation, but have reasons to believe that oxalic acid and monobromacetic acid are amongst them.

When tetrabromodiacetyl was treated with hydrogen peroxide, its yellow color disappeared slowly. A white flocculent precipitate formed while the dense powder dissolved. The colorless solution had a peculiar penetrating odor, and deposited, upon standing, another crop of the product in the form of long, colorless needles with a silky luster. From 3 to 4 grams of this substance were thus obtained from 10 grams of the diketone.

The mother liquor, still having the characteristic odor of the crystallized product, was extracted with ether, but the latter, on evaporating, left only a small quantity of an oily liquid.

The crystals were found to be insoluble in water, and very freely soluble in alcohol, ether, benzene, glacial acetic acid and other organic solvents. From an ethereal solution very beautiful, prismatic crystals, more than a centimeter long, were obtained. They belong without doubt to the rhombic system, and consist of several prisms, the orthopinacoid and a brachydome. From the solution in acetic acid the substance is reprecipitated in the form of long, fine needles, when much water is added. It melts at 72·8°, and at higher temperatures sublimes, apparently without decomposition.

Analyses of the carefully purified substance yielded:

	I. Per Cent.	II. Per Cent.	Calculated for C_3HBr_5O. Per Cent.
C	8·13	8·04	7·94
H	·56	·26	·22
Br	87·99	88·04	88·30
O	[3·32]	[3·66]	3·53

Determinations of the molecular weight by the cryoscopic method, by means of Beckmann's apparatus and glacial acetic acid as the solvent, gave:

I.

Used solvent	19·485	grams.
Substance	·1788	"
Depression	·084°	

II.

Solvent	19·663	grams.
Substance	·3360	"
Depression	·146°	

I.	II.	Calculated.
461	435	452

The composition and molecular weight correspond to the formula C_3HBr_5O, which is that of *pentabromacetone*. That this is really the compound we obtained is further proved by a comparison of the physical properties* with those observed by other chemists, as well as its behavior upon boiling with barium hydroxide; *bromoform* was produced and was identified, after distilling it in a current of steam, by its odor and boiling point, and the formation of phenylcarbylamine when the alcoholic solution was treated with aniline and caustic potash.

It is remarkable that an acetone derivative should result from the oxidation of a diketone, for methyl-ethyl ketone can be converted by oxidation into diacetyl.†

The oily product mentioned above, and which was extracted from the solution after the pentabromacetone had separated, may have been tribromacetone. It had a powerful odor, decomposed upon heating, and did not respond to the carbylamine reaction.

Attempts to oxidize tetrabromodiacetyl with nitric acid have not as yet given any definite results. Although the substance dissolves rapidly on warming in the concentrated, especially the red fuming, acid, the greater part of it separates again, on cooling or diluting with water, in large yellow crystals.

Cyanohydrins.—Another class of diacetyl derivatives to which we have lately given some attention, are the cyanohydrins.

Fittig and one of us have shown that diacetyl and hydrocyanic acid unite quantitatively to form a dicyanohydrin, and that this may be readily converted into dimethylracemic acid.

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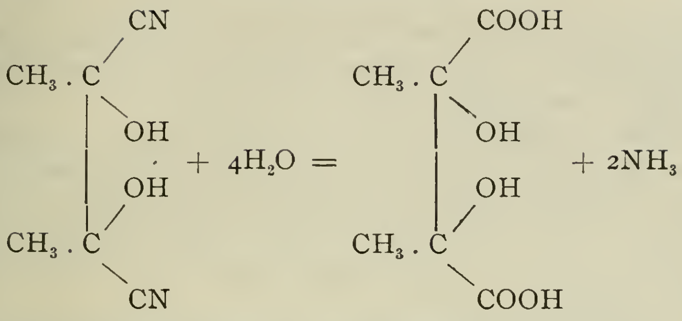
* The melting point is given by Beilstein (3d ed., p. 989) as 76°. Although we repeated the determination several times, using material purified with scrupulous care, and the best thermometers, it invariably gave the same result 72·8°.

† Fileti and Ponzio, *Gazz. chim. ital.*, **25**, 233.



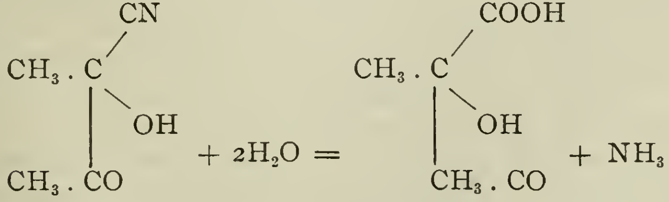
Our recent experiments were undertaken—

(1) To attempt the preparation of a monocyanohydrin of diacetyl.

(2) To produce halogen-substituted cyanohydrins.

If we succeeded in converting the latter into the corresponding acids, we would have the first derivatives of tartaric acid in which hydrogen is replaced by halogen.

Diacetyl and hydrocyanic acid (30 per cent. solution) were brought together in molecular proportions. A rise of temperature and the vanishing of the yellow color indicated that combination was taking place. The liquid was gently heated, and then allowed to stand for some time in a warm place. After extracting with ether, and evaporating this solvent, there remained a colorless, viscous liquid. This was placed over dehydrating materials, and repeatedly cooled to very low temperatures, without showing any signs of crystallizing or congealing. It was doubtless the expected compound, though probably very impure. We now attempted to produce the corresponding acid



by treatment with strong hydrochloric acid. This was tried in a number of ways; but although even the most concentrated acid (saturated at 0°) had no appreciable effect at ordinary temperatures, the slightest warming destroyed the compound, with formation of dark resinous products, from which an acid of definite composition could not be isolated.

More encouraging were the results of our experiments upon dibromodiacetyl. It was found to combine with hydrocyanic acid quite readily, and yielded a well-crystallized dicyanohydrin. From the ethereal extract it was obtained in fine colorless crystals, having a strong luster, and melting with decomposition at 177°.

Its composition is established by these determinations:

	Found.		Calculated.
	I. Per Cent.	II. Per Cent.	Per Cent.
N	9·38		9·39
Br	54·35	54·74	53·69

The excess of bromine is probably due to the formation of calcium cyanide when the substance is ignited with lime.

Experiments are in progress to transform the nitrile into the acid; the amide of the acid has been obtained in small quantities.

We have also found that tetrabromodiacetyl can be made to combine without difficulty with two molecules of hydrocyanic acid. The resulting body seems to be analogous to the tetrachlorodiacetyl dicyanohydrin described by Levy and Witte.* As yet, however, we have not prepared a sufficient quantity to warrant the publication of definite data.

Dichlorodiacetyl.—As Levy and his pupils† obtained their tetrachlorodiacetyl by a complicated process, the action of potassium chlorate and hydrochloric acid on chloranilic acid, we have tried to prepare it by direct chlorination of diacetyl. It was found that at first the action of chlorine upon the diketone, dissolved in carbon disulphide or chloroform, is quite energetic, but the only product we have so far obtained proves to be dichlorodiacetyl. It closely resembles the dibromo-derivative; soluble in carbon disulphide, chloroform, boiling petroleum ether and warm benzene, it crystallizes in yellowish, unctuous scales, melting at 124·5°. A chlorine determination gave:

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* *Ann.*, **254,** 98.

† *Ann.*, **249,** 93.

	Found. Per Cent.	Required for $C_4H_4Cl_2O$. Per Cent
Cl	45·63	45·80

Laboratory of the Central High School, Philadelphia.

CORRESPONDENCE.

INTERNATIONAL GEOLOGICAL CONGRESS, SEVENTH SESSION, ST. PETERSBURG, 1897.

Report of Dr. Joseph W. Richards, Delegate of the Institute.

To the President and Members of the Franklin Institute:

Your delegate to the Seventh International Geological Congress, assembled in St. Petersburg at the invitation of the Tsar, respectfully submits the following report:

The Congress was in session from August 29th to September 4th.

Previously to its opening, a number of the delegates participated in an excursion of fourteen days in Esthonia, under the direction of Fr. Schmidt; others in a trip of seven days into Finland, under the direction of I. Sederholm and W. Ramsay; while others, to the number of 120, embraced the opportunity offered to visit the Ural Mountains, and enjoyed an expedition of twenty-nine days in eastern Russia, from Moscow to Ekaterinsbourg and Perm. The members who participated in these expeditions were delighted with the lavish hospitality everywhere showered upon them, and will carry to their homes, in all quarters of the world, lasting remembrances of Russia's friendliness to the representatives of geological science.

It may here be remarked that, after the closing of the Congress, there is organized a trip of thirty days through Southern Russia and the Caucasus (*via* Moscow, Nijni, the Volga, Astrakhan, the Caspian Sea, Petrovsk, Vladi-Kavkaz, Tiflis, Baku, Batoum, Kertch, Sevastopol to Odessa), which will be participated in by nearly 300 geologists, and promises to be an incident of a lifetime.

On Saturday evening, August 28th, the Committee of Organization gave a reception to the members of the Congress in the rooms of the German Club, where, to the accompaniment of military music, in the comfortable rooms and spacious garden of the club, the assembled geologists renewed old, and laid the foundations of new, friendships. The strenuous efforts of the Committee of Organization to make the days of the Congress pass as pleasantly as possible, may be seen when it is noted that the entire club building, with all its accessories, was rented for the week of the Congress and placed at the disposal of the delegates as a rendezvous.

The formal opening of the Congress took place at 1 o'clock on the afternoon of August 29th, in the large hall of the Zoölogical Museum of the Academy of Sciences, which was beautifully decorated. The scene was a brilliant one, the members and officers being in full dress or uniform, with honors and badges of distinction, the whole scene centering about Their Highnesses the Grand Duke Constantine Constantinovitch and the Princess d'Oldenbourg, who graced the occasion by their presence. The Grand Duke, Honorary President of the Congress, greeted the assembly as follows:*

"In the name of His Majesty, the Emperor, our August Protector, I welcome the brilliant assembly of geologists united here, and I am happy to greet, in you, the representatives of the civilized countries of the entire world.

"It was twenty years ago, on the other side of the ocean, at Philadelphia, that there germinated for the first time the idea of the necessity of concordance in the works of geologists of different parts of the world, and it was decided that the first International Geological Congress would be held in Paris. Even then were plainly evident the series of questions which needed to be solved by the united work of the geologists of all countries. Besides these questions of the first importance, the sessions which have since been held in Bologna, Berlin, London, Washington and Zürich have brought forth a whole series of new questions, of a character equally international, and the solution of several of these has already led to startling results in the whole of contemporary geological literature.

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*The proceedings of the Congress were all held in the French language.

"Since the Congress of London, several of the members had expressed the desire to see the geologists meet in Russia. His Majesty, the Emperor Alexander III, received this wish kindly, and deigned to invite the Congress, then assembled at Washington, to hold its Seventh Session at St. Petersburg. From that time, work has been going on actively to receive in proper manner the members of the Congress. To afford to our guests the possibility of taking note, on the spot, of the geological peculiarities of our country, it was decided from the first that there would be made several long excursions across Russia. This project, however, could not have been realized without the generous assistance of His Majesty, the Emperor Nicholas II. Our gracious Sovereign immediately accorded very large assistance in contributing to the success of these excursions.

"At the present time, many among you, sirs, have already been able to realize part of the projected excursions. A goodly number among you have already twice traversed European Russia and have visited the Asiatic slope of the Urals, that cradle of our mineral industry. You have had, it is true, many difficulties to vanquish in this tour, but I am pleased to believe, sirs, that the privations which you have had to endure have been compensated for by the new and interesting things which you have seen on your journey.

"Others among you have visited Finland, in excursions full of scientific interest, thanks to the enlightened co-operation of our colleagues, the geologists of Finland.

"A certain number, finally, have been able to traverse the Baltic provinces, the coast of Russia, which is, without doubt, the best studied in its geological relations.

"In all your excursions, you have been able to observe the cordial reception which is given in Russia to the representatives of science.

"Now that you have collected new material for your studies, and have seen with your own eyes that which most of you knew only from the books, you are about to commence the work which is to occupy your attention in St. Petersburg.

"Permit me, sirs, to express the wish that the flourishing tree of geological science, which has already borne such good fruit in the preceding sessions, will not bear in less abundance in the Congress of St. Petersburg, and that our present reunion may give a report of a scientific interest no less satisfactory than those which have been published after each of the previous six sessions.

"I declare the Seventh Session of the International Geologic Congress opened."

After the subsidence of the applause which followed this happy address, Madame, The Princess d'Oldenbourg, President of the Imperial Mineralogical Society, welcomed the Congress in the name of the Society, which was founded under Imperial protection in 1817.

The Grand Duke Alexandre Mikhaïlovitch telegraphed a welcome in the name of the Imperial Society of Naturalists, of which he is President.

The Russian Minister of Agriculture then took the floor, and in a very agreeable manner greeted the assembly, gave a *résumé* of the labors of Russian geologists, noted the intense activity at present shown in all parts of the Empire, especially in Siberia, and declared that: "It is at this moment of ever-increasing development, of even feverish activity, in the domain of geologic science, that we salute as our guests the most eminent geologists of the entire world. This reunion is an event of capital importance, which will leave for all time its trace in the scientific history of our country."

The business of the assembly was then begun. M. Renevier, President of the last session of the Congress, took the floor and announced the recommendations which the Council of the Congress had adopted. The bureau named included, as "Former Honorary President," James Hall, of the United States; as President, Karpinsky, of Russia; as Secretary, Tschernyschew, of Russia; and as Vice-Presidents, thirty distinguished geologists from different countries, among whom were: Marsh, Emerson, Frazer and Emmons from the United

States. The assembly ratifying the recommendations of the Council, M. Renevier resigned the Presidency to M. Karpinsky. The latter took the floor and addressed the Congress at some length. Part of the address was as follows:

"Before beginning our work, I deem it my first duty to render final homage to the memory of the members of former Congresses whom we have had the profound sorrow to lose since our last session. We regret deeply not to see amongst us the Honorary President of the London Congress, Huxley, nor its President, Prestwich; nor the President of the Berlin Congress, Beyrich, nor the illustrious Daubrée. * * * We see no longer amongst us, either, the celebrated Danish savant, Swendstrup, Posepny, the Marquis de Saporta, Bornemann, nor Antonio del Castillo, the founder of the Geological Bureau of Mexico.

"These were all more or less advanced in age, but our science has also lost men full of life and who gave us the brightest hopes. Such were Cope, one of the most illustrious savants of the New World; de Foullon, the worthy Austrian geologist; Leon du Pasquier and Marschal Hall. * * *

"We cannot cite here all the losses we have made; there are many others whom we could name. Let us rise, gentlemen, to honor their memory.

"Passing to the task imposed upon us by our reunion, I would recall to you that the Committee of Organization judges it of the first importance to take up in our session the vital question of the unification of the nomenclature, and that first of all the Congress ought to decide which of the two chronological classifications of sedimentary formations it wishes to preserve in the science, viz.:

"(1) The artificial classification, based solely on historical facts; or

"(2) The natural classification, which is based as much on general physico-geographic changes, common to all the world, as on the knowledge of fauna, and *not* on the accidental limits of diverse divisions called after the name of the country where they have been recognized for the first time.

"Finally, it is desirable that the Congress throw light on a second question of principle, that of rules to be followed in the introduction of new terms in stratigraphic nomenclature. It is in the highest degree desirable that the Congress, which has already established rules for paleontologic nomenclature, should establish the conditions which authorize the application of new terms to new deposits.

"Another question, of no less absolute necessity, is petrographic nomenclature.

"The development of science ought to be entirely free, without being encumbered by superfluous rules. The remarkable progress made recently in all branches of geologic science has opened up a series of new horizons; these new fields require new terms, which are wanting in scientific language. But, as always happens in such cases, the new terms have multiplied too fast, and never has geology suffered from such a superabundance of new words. We are fast approaching a new Tower of Babel.

"These questions can only be decided by universal agreement among geologists, and no one doubts that the Congress ought to decide them. When nine-tenths or even one-half of the geologists are perfectly in accord upon the necessity of a rule to be followed in order to preserve clearness in scientific language, all the others should finally conform gradually to that rule.

"I cannot close, sirs, without saying that it is a very great pleasure for all us Russians to see assembled in our capital so many geologists of the entire world. That which pleases me, especially (I do not conceal it), is that on returning to your homes you will enlighten your countrymen concerning our country, so little known to most of them. The true geologic science is not confined to one's own country, and it is only the fraternal work of all the geologists of the world which can enlighten us on the structure and evolution of the earth, our great fatherland. This fraternal accord is one of the most beautiful aspects of scientific congresses in general, and in no case can the results be more beneficial than in the progress of the science to which our assembly is consecrated."

M. Karpinsky was succeeded by M. Tschernyschew, Secretary of the Congress, who recapitulated briefly the history of the organization of this Congress. The opening exercises were then closed by the Grand Duke Constantine Constantinovitch.

On Tuesday, August 31st, the Congress visited the Tsar's palace, Peterhof, and was most royally received.

On Wednesday, September 1st, the members were tendered a reception in the Hôtel de Ville, by the Mayor of St. Petersburg and the town council.

On Thursday, September 2d, the Congress was the guest of the Senate of Finland, at the Cascade of Imatra.

The other days were occupied by a sitting of the Council at 9 A.M.; a general assembly for the discussion of general questions at 10.30 A.M., and a meeting for the reading and discussion of papers at 3 P.M. On September 5th, the Congress was formally closed at 1 o'clock P.M., at which sitting the usual votes of thanks were passed. and amid general felicitations, the Congress adjourned to meet next in Paris, in 1900.

The record of the business of the session will be found in detail in the reports sent herewith.

Respectfully submitted,

JOSEPH W. RICHARDS.

ST. PETERSBURG, SEPTEMBER 4, 1897.

NOTES AND COMMENTS.*

WHAT IS ELECTRICITY?

The *American Electrician* condenses from the *London Engineering's* review of Prof. Trowbridge's new book, "What is Electricity?" as follows: The writer says that in spite of the all-round progress made during the last thirty years, we know no more about the essential nature of electricity than did Benjamin Franklin 150 years ago. The several explanations offered, based upon the ether, or ether and matter associated, merely substitute one unknown for another. "After all, what is matter? What is the ether? How is matter associated with the ether? To such fundamental questions we can return no other answer than the now famous ignoramus. They make, or tend to make, us painfully conscious of the infinitude of our nescience." The writer of the review adds that Lord Kelvin must have been brooding over these provoking unknowns when he wrote to him in 1892: "Tell me what electricity is, and I'll tell you all the rest." This inability to detect electricity in its primordial form need, however, exert no distrustful, no depressing effects on the mind of the student of physical science. "Let him remember that a ray of light is an unexplained phenomenon; yet what wonderful truths are revealed to Fresnel, what knowledge has been wrested from it by means of the spectroscope, and what marvels is it not every day recording on photographic plates! If he feels himself morosely affected by this agnosticism, let him recall the astronomical phenomena which are accurately calculated years in advance without any knowledge whatever of the nature of gravitation; or let him think of that masterly bit of analysis which led to the discovery of argon without any knowledge on the part of Lord Rayleigh or Prof. Ramsay, of what chemical affinity is. If he is a practical man, let him reflect that the engineer lives amid stresses and strains, and though ignoring the intimate nature of the forces which he uses, builds up powerful engines and dynamos, and as successfully tunnels a Mont Cénis as he throws a bridge across the Hudson or the Firth of Forth."

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* From the Secretary's monthly reports.

PHOTOGRAPHS WITHOUT LIGHT.

In a recent paper, read by Dr. Russell before the Royal Society, he described the results of a series of experiments which, to photographers, almost rival the discovery of the X-rays. From time to time various experimenters have claimed to obtain photographs by the long exposure of bodies to sensitive photographic surfaces without the action of light. As far as we are aware, however, with the exception of Becquerel's and Colson's experiments, the precautions taken for the exclusion of extraneous light have not been such as to place these experiments above suspicion.

There now seems little room for doubt that many of the common substances with which we are surrounded have the property of emitting invisible active radiations, which can pass through many bodies that we have been in the habit of regarding as opaque. Becquerel some time ago showed that different compounds of uranium, if allowed to remain on a sensitive photographic plate for some days in the dark, had considerable action on the film, and if the plate was developed in the usual way, a photograph of the body was obtained.

Dr. Russell, in repeating Becquerel's experiments, has discovered that this particular action is by no means confined to uranium salts, but that many of the metals and other bodies, such as wood, charcoal, copal, straw, etc., possess it in a marked degree. The radiations from these bodies, however, differ in one very important particular from those given out by the uranium compounds. While the latter readily pass through glass, the former are completely stopped by it. Mr. Colson, in January last, described the action of zinc, cadmium and magnesium on photographic films in the dark. At the time of making his experiments, Dr. Russell was not aware of this, and, consequently, his results are independently confirmed.

Starting with the metals mercury, zinc, magnesium, cadmium, nickel, aluminum, pewter, fusible metal, lead, bismuth, tin, cobalt and antimony, he found that all these, after a week's exposure near a sensitive plate in the dark, produced a distinct effect upon the plate, while gold, iron and copper only showed a very slight effect. The action is not in any way due to "contact phenomena," as a polished surface of zinc with a design scratched on it gave a distinct image of the markings when not touching the plate, and even when thin screens of gutta percha or celluloid were interposed between the sensitive plate and the zinc surface. Some metals were then coated with copal varnish, to see if this would interfere with the effect. It was found that the image was more rather than less distinct.

In another set of experiments, cardboard pill boxes were used for inclosing certain substances before allowing them to act upon the photographic plate. It was discovered that an empty box emitted active radiations, giving a most distinct image. This suggested experiments with different cardboards, when it was found that the better qualities were quite inactive, while the common varieties, known as straw-board, had considerable action on the plates. Among the other bodies experimented with were green and dry woods, both of which were active. A section from a young larch tree gave an excellent image, showing rings and layer of bark. Charcoal was also found to be active, but lost its activity if heated for several hours in a closed crucible.

The results obtained with printers' ink were very interesting. In many cases they produced no action at all, and in other cases they were remarkably active. The ink used by the *Westminster Gazette*, the *Standard*, and the *Daily Graphic* gave excellent pictures of the printing. The *Times* showed not quite such good results, while ink of the *Morning Post* and the *Echo* had no action at all.

What is this mysterious force? Its nature has still to be discovered. Two points seem to have been established. The first is that an increase of the temperature of the body greatly increases its activity; the second, that aqueous vapor in no way assists the action. Bodies which, at 0° C. had no action whatever, at 70° C. gave distinct images. It has further been suggested that the chemical action is caused by a finely attenuated vapor given on by the different metals and other bodies. It is far more likely to be due to some hidden form of energy more or less akin to what has been paradoxically, but suggestively, called dark light.

THE BOSTON SUBWAY OPEN.

A part of the subway, Boston's new underground thoroughfare for street cars, was open to public traffic the morning of September 1st. The sections to be operated for the present are about three-quarters of a mile long; other sections will probably be opened in the spring. The trip from the public garden entrance to Park Street was made in a little over four minutes; 100,000 people rode through the subway the day that it was opened. The contract for building the last section near the Union Station has been awarded and the work started. The transit commissioners believe that before next summer the entire subway will be in use and Tremont Street wholly free from cars.

METALLURGICAL ITEMS.

The following items of interest are gleaned from the current impressions of the *Engineering and Mining Journal:*

Dr. Borchers, in the *Zeitschrift für Elektrochemie* (June 20th), reviews a new process for winning *phosphorus and calcium carbide from Thomas slag.* In this process tricalcium phosphate is mixed with an excess of powdered carbon, and heated in an electric furnace, whereby calcium carbide, phosphorus and carbonic oxide are formed. The phosphorus passes over into a condenser and is recovered, the yield being claimed to be 80 per cent. of the theoretical. Dr. Borchers describes a series of experiments made by himself with a view of converting the phosphates of these slags into phosphides, the latter to serve as a deoxidizing material for overblown iron. The results, however, proved negative, the lime in the slag giving off its phosphorus, and going into calcium carbide.——An interesting occurrence of *tin ore and diamonds*, which is, we think, unique, is described in the recently issued report of the Department of Mines and Agriculture of New South Wales for 1896. Gravel containing cassiterite in workable quantity, together with diamonds, was discovered last year at Boggy Camp, fifteen miles west of Tingha, which has been for some time a productive tin field. The pay streak at Boggy Camp, which is from 30 to 50 feet deep, averages from 2 to 7 feet in thickness, the width of the lead not yet having been ascertained. One load of gravel yielded 515 stones of 184 carats aggregate weight, and forty-two loads furnished 600 carats of diamonds, and tin-stone at the rate of 13 pounds per load. The pay streak is a quartz-pebble drift underlying a large hill of basalt. Mr. E. F. Pittman, the Government geologist, who examined the occurrence, considers that the basalt filled what was originally an oval-shaped depression. The gravel rests on granite, and granite can be traced entirely around the basalt. The diamonds are white and of good quality, and it is thought that when the gravel is drained the district will make a considerable production.——At the International Congress for Methods of Testing, at Stockholm, August 23d–25th, Dr. Wedding reported that the proposal to form *an international laboratory for investigating the chemical analysis of iron* had met with warm support in influential quarters, and that liberal annual contributions to its maintenance for ten years had been promised by the Steel Company of Scotland, Consett Iron Works, Sir Bernhard Samuelson, Sir Lowthian Bell, Krupp, of Essen, Cockerill's Steel Works and other Continental firms. The support received was considered by the Congress sufficient to warrant beginning operations, and it was decided to endeavor to open the laboratory by January 1st next, in a building at Zürich, provided for the purpose by the Swiss Government.——E. Piñerúa (*Compes Rend.* 124 pp. 862–863) states that *nickel chloride and aluminum chloride are insoluble in ether*, saturated at a low temperature with hydrochloric acid, while the chlorides of cobalt and of iron dissolve in it readily. The mixed chlorides of nickel, cobalt and iron are dissolved in as little water as possible, a mixture (about 20 c.c. to 0·3 g. of the chlorides) of equal volumes of ether and fuming hydrochloric acid is added, and the whole, in a bath of salt and ice, saturated with hydrochloric acid gas. The nickel separates as a heavy yellow crystalline precipitate, which is washed, first by decantation, and then on the filter, with ether saturated with hydrochloric acid, and then converted into one of the ordinary forms in which nickel is weighed. Cobalt remaining in solution gives a deep-blue color to the liquid, iron a green; small quantities of iron perceptibly change the blue of the cobalt solution; hence this method affords a ready qualitative test for the other metals in reputedly pure salts of cobalt or of nickel. Where much iron is associated with nickel the precipitate retains traces of iron, and should, therefore, after washing, be re-dissolved and re-precipitated. Exactly the same method is pursued to separate cobalt from aluminum. The method gives very exact results.

H. W. Wiley (*Journal American Chemical Society*, 1897, 19, 258–261) states that the following method has been worked out by K. P. McElroy: The *waste platinum from potash determinations* is collected, dissolved in water, and aluminum in the form of clippings or turnings added to the hot solution. In a few minutes a platinum-aluminum couple is formed, and reduction proceeds vigorously. The addition of hydrochloric acid is advisable to facilitate the deposition of the platinum, and when the reduction is complete, more hydrochloric acid is added to dissolve the excess of aluminum. The spongy platinum is well washed by decantation, and treated with nitric acid to remove any traces of copper; it is again washed, and dissolved in aqua regia (5 parts of hydrochloric to 1 part of nitric acid). The solution thus obtained is evaporated, dilute hydrochloric acid added, and re-evaporated. Should nitrous fumes be evolved on the addition of water, the solution is evaporated, and this treatment continued until the nitric acid is removed. The resulting solution of platinum chloride is then diluted and filtered —— Siemens & Halske's latest process for the *electrolytic winning of zinc* consists of the treatment of the dry ore (blende or blende mixed with galena) with chlorine gas until chlorination is complete, solution of the chlorides in water, or water to which a little NaCl or HCl has been added, and electrolysis of the solution between an insoluble anode and a metallic cathode, whereby metallic zinc is precipitated and chlorine set free, which is used for the treatment of a fresh lot of ore. Lead goes partly into the solution, but silver remains with the insoluble residue. It is never advisable to carry on the electrolysis so far as to effect complete deposition of the chlorides on account of the cost of the electrical energy; for this reason an excess of chlorine is provided in the solution by the addition of common salt. The undecomposed chlorides are not lost, however, since the nearly spent solution from the electrolytic vats is employed as lixiviant for fresh lots of ore.—— J. R. Mourelo (*Comptes Rendus*, 1897, 124, pp. 1024–1026 and pp. 1521–1523) has experimented with several methods for the preparation of *highly phosphorescent strontium sulphide*, and finds that by far the best results, so far as phosphorescent power of the product is concerned, are obtained as follows: An intimate mixture of 285 g. of commercial strontium carbonate, 62 g. of flowers of sulphur, 4 g. of crystallized sodium carbonate, 2·5 g. of salt, and 0·4 g. of bismuth subnitrate is placed in a crucible, covered with a layer of coarsely powdered starch, and submitted for five hours to a bright red heat, and subsequently allowed to cool very slowly (10–12 hours). A white, friable mass is thus obtained, which develops a fine greenish-blue fluoresence when exposed for about one second to daylight, and so intense as to be plainly visible in a shaded situation. The author remarks, however, in conclusion, that the greater number of his preparations became perfectly inert when powdered, although in some instances the phosphorescent power of the sulphide was restored by re-ignition in contact with starch. While the phosphorescence of calcium sulphide varies considerably in color, with even slight variations in the conditions of its preparation, that of strontium sulphide is remarkably constant, being a more or less greenish-blue. The tint varies slightly, and the intensity to a greater degree, with the source of the sulphide; the most intense and the greenest being that of the sulphide prepared from a mixture of strontium and sodium carbonates, sodium chloride and bismuth subnitrate, while the least intense is the bluer phosphorescence of the sulphide reduced from the sulphate by lampblack.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 20, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 20, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 78 members and visitors.

Additions to membership since last report, 11.

The President opened the proceedings by giving a brief statement of the pending negotiations between the Institute and the Philadelphia Museums, with the object of holding, in the autumn of 1898, a national exhibition under the joint patronage of the two bodies.

The Secretary reported a vacancy in the Committee on Science and the Arts caused by the resignation of Dr. W. C. Head.

Mr. Arthur Falkenau was elected to the vacant position.

The meeting then proceeded to the business announced on the bulletin, to wit: The consideration of the subject of "Improved Furnaces and Automatic Stokers."

The following inventions were described and shown either with lantern slides or by model, viz.:

The Murphy Automatic Stoker, manufactured by the Murphy Iron Works· Detroit, Mich. Represented by Mr. —— Cotton.

The American Stoker, manufactured by the American Stoker Company, Dayton, O. Represented by Mr. C. H. Bierbaum.

The Acme Stoker, manufactured by the Falls River Rivet and Machine Company, Cuyahoga Falls, O. Represented by Mr. Wm. E. Gray.

The Coxe Mechanical Stoking Furnace, manufactured by the Coxe Iron Manufacturing Company, New York. Represented by Mr. M. C. Jenkins.

The Arndt Econometer, manufactured by Mr. Joseph Wilckes, New York. Represented by Mr. A. Falkenau.

The Hutchinson Smokeless Furnace. Represented by Colonel C. Wolsley Coxe.

The following devices were presented by the Secretary, from written descriptions furnished by the manufacturers, viz.:

The McKenzie Smokeless Furnace, manufactured by the McKenzie Furnace Company, Chicago.

The Black Diamond Smokeless Furnace, manufactured by Bowe & Co., Chicago.

The Columbia Mechanical Stoker, manufactured by the Columbia Stoker Company, Holyoke, Mass.

The Davies Stoker, manufactured by the Davies Stoker Company, Bridgeport, Pa.

At the close of these presentations, the subject was thrown open for general discussion. Messrs. James Christie, Thos. Shaw, Spencer Fullerton and others participated, and the matter was referred to the Committee on Publications.

The President made an appropriately worded reference to the recent death of Dr. Wm. H. Ford, for many years President of the Bureau of Health of the City of Philadelphia, who had not only been instrumental in securing the reference by the Board of Health of the question of the smoke nuisance as it affects Philadelphia, to the Institute for advice and co-operation, but had also exhibited much personal interest in the discussion of the subject at the Institute meetings during the past few months. The President suggested that some action by the meeting would be fitting as the expression of the sentiment of the Institute, respecting the loss which the city has suffered in the death of a most intelligent and efficient public servant.

It was thereupon voted that the Secretary be directed to record on the minutes of the meeting, the expression of the Institute's appreciation of Dr. Ford's valued service as President of the Board of Health, and its regret at his death.

The Secretary presented the report of Dr. Joseph W. Richards, delegate of the Institute to the Seventh International Congress of Geologists in St. Petersburg. Referred to the Committee on Publications.

Adjourned. Wm. H. Wahl, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held October 6, 1897.*]

Mr. James Christie in the chair.

Reports on the following subjects passed first reading:

Balanced Locomotive Driving-Wheel, Philip Z. Davis, Philadelphia.

Holophane Globes, George A. Macbeth Company, Pittsburgh, Pa.

Combination Book-Shelf and Book-Support, August Lundberg, Worcester, Mass.

Pneumatic Pyrometer, Uehling, Steinbart Company, Limited, New York.

Reports on the following subjects were adopted:

Testing Machine for Measuring the Intensities of Impulsive Forces.—B. W. Dunn, Lieut. U. S. A., Frankford Arsenal, Philadelphia.

Abstract.—The purpose of this apparatus is to obtain a permanent diagrammatic record of the varying compression produced in a test specimen by a blow, together with an accurate time scale by which the duration of the blow in its component parts can be measured, it having been found that the compression obtained in a static testing machine varies slightly with the time during which pressure is applied.

As these quantities are extremely minute, the record of the Dunn machine is made in magnified form by two rays of light deflected, respectively, by the compression of the test specimen and by the vibration of a tuning-fork, so that they travel over a photographic film carried on the periphery of a rapidly revolving cylinder. The description of this extremely delicate and automatically operating apparatus is not susceptible of intelligible abstract without the use of illustrations. The reader is, therefore, referred to the text of the report. An approximate notion of its possible utility in the solution of problems outside of the province of the ordnance engineer, may be obtained from the following extract from the report:

"An observer standing in the dark-room and looking toward the revolving cylinder, sees, on its surface, at the instant of impact (*i. e.*, of the test weight on test specimen), a brilliant vertical line of light, whose duration is less than that of a flash of lightning. The photographic film on the rapidly-spinning cylinder, however, has received, in this inconceivably short interval of time, a permanent record of many important events, and arranged them in chronological order, to be examined and studied at our leisure."

The report concludes: "In view of the originality of the investigations made, and of the scope of the apparatus devised by him for measuring the varying intensity of an impulsive force, the award of the John Scott Legacy Medal and Premium is recommended to applicant." [*Sub-Committee.*—L. F. Rondinella, Geo. F. Stradling, Wilfred Lewis, Hugo Bilgram, Luigi D'Auria.]

Process of, and Apparatus for, Manufacturing Mosaics, etc.—Herman C. Mueller, Zanesville, O.

ABSTRACT.—This invention is the subject of U. S letters-patent, No. 537,703, April 16, 1895, to Herman C. Mueller, and relates to the class of dry-press processes. It consists in part of an improved method of distributing the colored clays for the inlaid designs to the compartments of a suitable frame, by sifting the colored material successively through specially prepared stencils of stiff paper; and in part, of an improved "cell-frame" for holding the body of the colored clays. By means of this improved "cell-frame" and the paper stencils through which the clays are sifted, any design, or part of a design, of large area, falling on a single tile, can be executed without the use of the so-called "cloissonné" or compartment frame, as in previous methods for doing similar work, and the expense of providing work of this class is thus very materially reduced.

The Sub-Committee is unanimous in its belief that Mr. Mueller's invention marks a distinct step in advance in the art to which it relates, and that it offers an admirable means of greatly extending the application of polychromatic decoration in architecture—something of which architecture of the present day is very much in need.

The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Wm. C. Head, Chairman; Edward S. Morse, W. H. Holmes, Edwin A. Barber, L. W. Miller, Edward Hart, Wm. H. Wahl.]

Arndt's Econometer.—Joseph Wilckes, New York.

ABSTRACT.—This invention is an instrument for measuring the specific gravity of gases, and is especially designed for the continuous measurement and indication of the proportion of carbon dioxide (CO_2) escaping in the flow of the products of combustion of steam-boiler furnaces. It is protected by letters-patent of the U. S., No. 527,397, October 16, 1894, to Max Arndt, of Aix-la-Chapelle, Germany.

The apparatus consists essentially of a balance beam carrying at each extremity a globular glass vessel (both of same volume). Through one of these, by suitable connections, the (dried) furnace gas, taken in a continuous stream from the flue of the furnace, is drawn by means of an aspirator. The other globe is filled with air. The balance is sufficiently delicate to record the presence of very small proportions of carbon dioxide in the flue gases, the percentages of same being indicated continuously by the pointer of the balance passing over a graduated scale. The details of the apparatus must be sought for in the report.

The tests of the Sub-Committee with one of these instruments in service at the Baldwin Locomotive Works, in this city, were highly satisfactory, and showed that its indications did not vary appreciably from those obtained by chemical analysis.

The report finds that the claims of the applicant were fully substantiated.

The award of the Elliott Cresson Medal is recommended to the inventor. [*Sub-Committee.*—Wm. M. Barr, Chairman; Arthur Falkenau.]

Improvements in Vehicle Wheels.—E. L. Markley, Royersford, Pa.

ABSTRACT.—This invention relates to an improvement in vehicle wheels, covered by U. S. letters-patent No. 569,703, October 2, 1896, to George P. Yeakel.

The improvement consists essentially of a tire made in two parts, a thin inner strip, called by applicant the plate; and the outer part, or tire proper, which may be flat on the outside, where there is only the steel tire, or recessed for carrying a rubber tire. The plate is rolled with a channel in the center, correspondingly projecting on the other side, which is the outside, with its edges turned into flanges embracing the rim, which flanges are partly turned before the plate is put on the wheel. The tire proper is rolled with a channel on the inside corresponding to the projection on the plate.

In putting on the tire, the plate is bent approximately to the shape and size of the wheel, and the tire proper having been heated, is shrunk on over it, compressing it closely on the wheel.

After the tire has been so shrunk on, the plate is pressed between rollers, which complete the flanging, pressing the flanges into the rim. The plate is held in place on the rim by the flanges, and the tire proper on the plate by the corresponding projection and channel. The joints of the rim are further held together by a short bar, sunk into the rim on the outside, in which is a bolt holding a clip on the inside. No tire-bolts are used.

Comparative experiments, made under the Sub-Committee's direction, on wagons similar in all respects and doing the same work—one being furnished a set of these tires and the others having ordinary tires, failed to show any superiority in the Yeakel tires over those in common use. [*Sub-Committee.*—G. M. Eldridge, chairman; H. R. Heyl, Spencer Fullerton.]

Investigations in the Molecular Physics of Cast Iron.—A. E. Outerbridge, Jr., Philadelphia.

ABSTRACT.—The scope and general character of Mr. Outerbridge's observations and studies of the molecular changes taking place in cast iron under the influence of continued vibration have already been set forth *in extenso* in the JOURNAL, and need not, therefore, be repeated.

The Sub-Committee confirmed the correctness of these observations and inferences by a series of experiments conducted in the foundry of the Camden Iron Works, the results of which are appended to the report.

The Sub-Committee's opinion of the merits of this work is concisely stated in the following extract from the report:

The fact that a certain molecular change takes place in cast iron in the course of time, has been known and recognized for a long time, and that this change tends to relieve the internal strains and render the casting tougher, has often been noticed and acted on, although in a very crude way ; but so far as the Sub-Committee has been able to learn, Mr. Outerbridge was the first to make a careful study of this and to note that the change may be hastened by impact, and the maximum strengthening effect produced in a short time, and also to make a scientific study of the phenomenon. Great credit is due to Mr. Outerbridge for the initial observation and the careful work dependent thereon. The results of his studies, given for the first time at the meeting of the American Institute of Mining Engineers (February 20, 1896), have since attracted widespread interest and discussion, but nothing growing out of this has shown that any one either in this country or abroad, has anticipated Mr. Outerbridge in this work.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—C. J. Prince, chairman ; Wm. C. Henderson, Wm. R. Webster, Gus. Henning.]

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, September 21, Dr. Lee K. Frankel, Vice-President, in the chair.

Dr. Harry F. Keller presented a communication on "Some Derivatives of Diacetyl."

Prof. O. C. S. Carter read a paper on "The Upper Schuylkill," devoted specially to a consideration of the nature and causes of the impurities in the upper river waters, and the influence by which the same are neutralized by natural causes.

Stated Meeting, October 19th, Dr. Frankel in the chair. Dr. Keller made some "Remarks on the Analysis of Electrolytic Copper." Mr. Philip Maas made a communication on the "Composition of Certain Vanadium Minerals from Leadville, Col." Dr. Wahl exhibited specimens of magnesia fused in the electric furnace ; also specimens of steel-lined aluminum culinary ware.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, October 13, Mr. Benj. Smith Lyman, President, in the chair. The following communications were presented : "Some Remarks on Wired Glass," by Francis Schumann. "The Econometer and Specific Gravity Apparatus, for Automatically Indicating the Condition of Combustion in Furnaces," by Arthur Falkenau. "Copper Traces in Bucks and Montgomery Counties," by Benj. Smith Lyman. Dr. Wahl described and showed in operation the Burton Electric Liquid Forge.

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VOL. CXLIV DECEMBER, 1897 No. 6

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THE FRANKLIN INSTITUTE.

Stated meetings, September 15 and October 20, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH ESPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA—IMPROVED FURNACES AND MECHANICAL STOKERS.

VICARS' AUTOMATIC MECHANICAL STOKER.*

MR. WILLIAM H. THORNE:—The subject of the prevention of smoke from boiler furnaces has been so thoroughly discussed here, that it is unnecessary for me to do more than touch upon it.

The whole question of steam production presented itself to William Sellers & Co. years ago, not so much in regard to

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*Manufactured by Wm. Sellers & Co., Incorporated, Philadelphia.

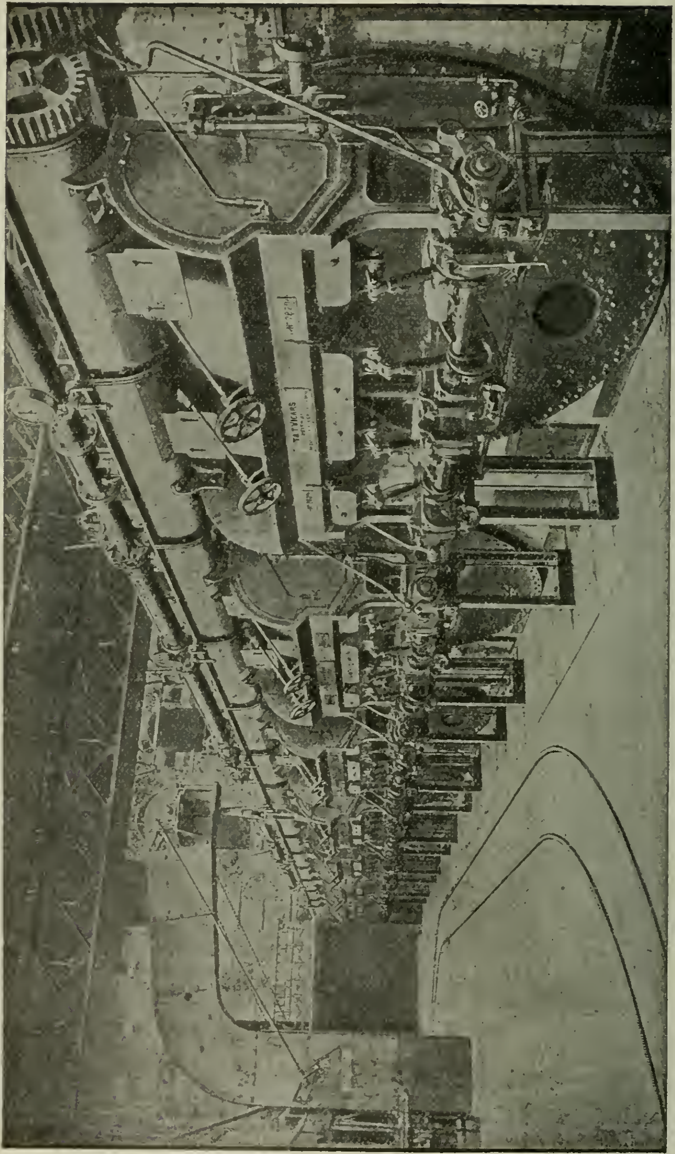

FIG. 1.—Battery of internally-fired boilers fitted with Vicars' automatic stokers.

the smoke nuisance, as in reference to the employment of cheap grades of coal, to the economical production of steam, to the orderly and systematic conduct of the boiler plant, and to the bringing of that department of the works up to the standard of the others.

Recognizing that the English had been confronted with the same problem to a greater extent, and for a longer period of time, and under worse conditions, and that they were very thorough in their investigations and persistent in their efforts to overcome difficulties, William Sellers & Co. made a study of what had been accomplished in England, with the idea of selecting the system best suited for use here.

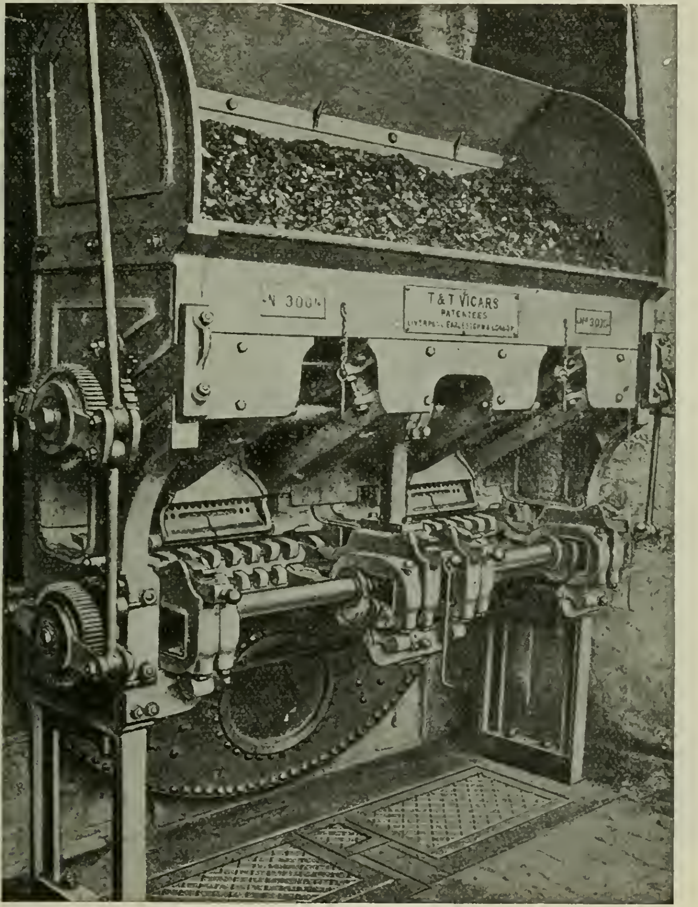

FIG. 2.

The result was that one of Vicars' automatic stokers was purchased in England and installed in the Sellers' works in Philadelphia.

By its use, we were able to burn bituminous slack with perfect success and without any smoke, the boiler service was brought into order, a material economy was effected, and, the heat in the furnaces being maintained so constant and regular, the time lost in overhauling and repairs of the boiler was very much reduced—an entirely unexpected source of saving and safety.

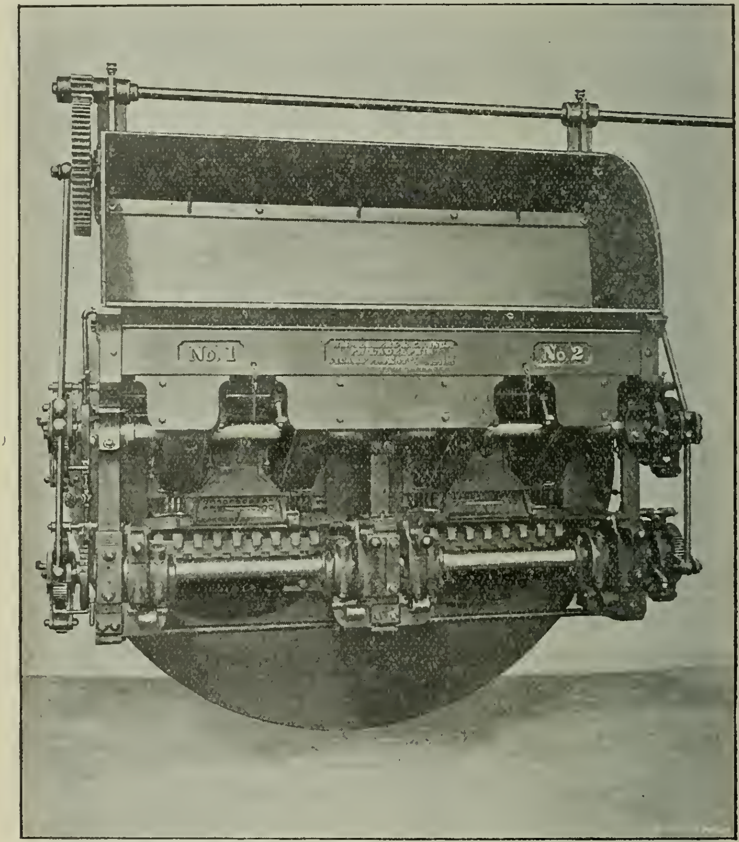

Fig. 3.

The use of the stoker having proved so satisfactory, the exclusive right for its manufacture and sale in the United States was obtained. Various modifications to suit American requirements have since been made, and these requirements are characteristic and exacting. The so-called conservatism of the English induces them to work a long time in producing a good thing, but when its value is established, they adhere to it tenaciously. Consequently we find great uniformity in their types and proportions of boilers, which renders the problem of the application of stokers a comparatively simple one.

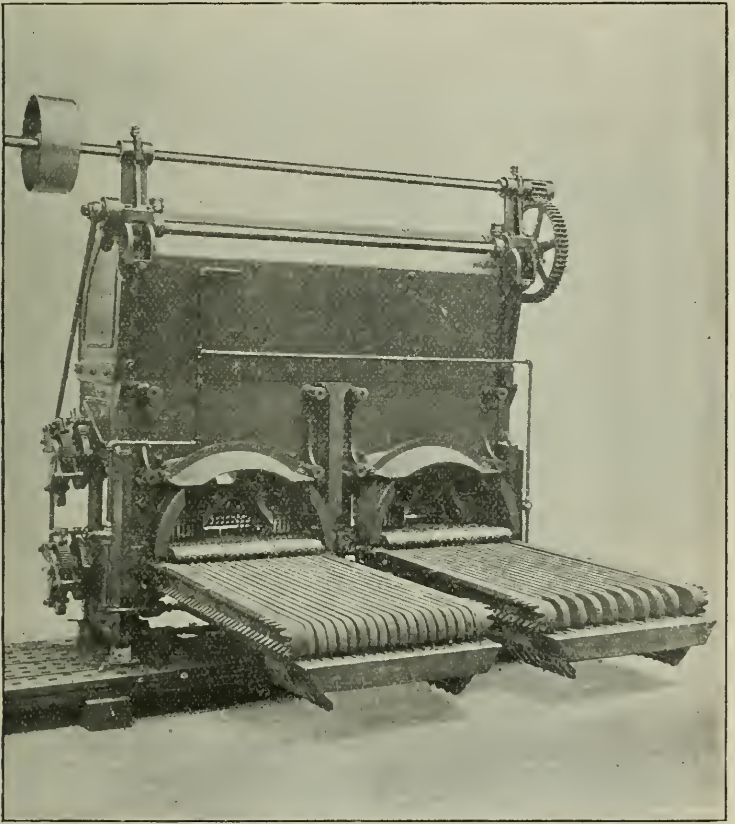

FIG. 4.

In this country the kinds and sizes of boilers are legion, and the conditions so variable that each case must be carefully studied and the stoker rearranged and proportioned to suit.

I will now endeavor, by means of the illustrations, to explain construction and operation of the "Vicar's Stoker," and its application to different types of boilers.

Fig. 1 shows a large steam plant of internally-fired double-flue boilers equipped with these stokers. Each pair of furnaces has a large hopper, which is kept supplied with coal by means of the overhead conveyor, thus avoiding separate piles in front of each boiler and minimizing the labor, dirt and cost of handling. The coal is stored in the cellar, from which it is raised by means of the elevator, shown in the background, and distributed by an endless screw in a trough extending over all the hoppers. Various types of coal conveyors are used, depending upon local and financial conditions.

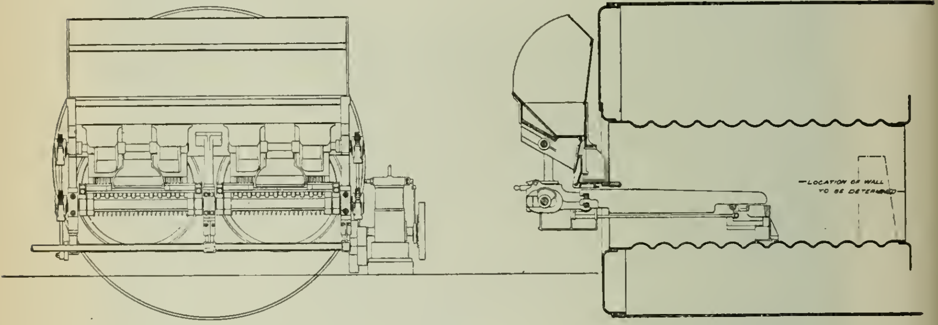

FIG. 5.

Fig. 2 is a view of the stoker that we imported from England, as it appears in use on one of our internally-fired Galloway boilers. In this case the hopper is kept filled by hand-shoveling, and, from our experience with it, we are convinced, contrary to the popular opinion, that the installation of a stoker on one boiler only is a profitable investment.

Fig. 3 is a front view of the stoker as built by us for internally-fired boilers, and, by means of it and the next view, I will endeavor to describe the details of the apparatus. In the bottom of the hopper are four openings into four inclined chutes, one on each side of each furnace door. In each chute is a plunger, which can be slowly pushed down by means of a tooth on the horizontal shaft engaging with a tooth in the top side of the plunger, and brought back when this same tooth engages with a tooth in the bottom side of the plunger. Each pair of plungers is operated by a separate shaft, and

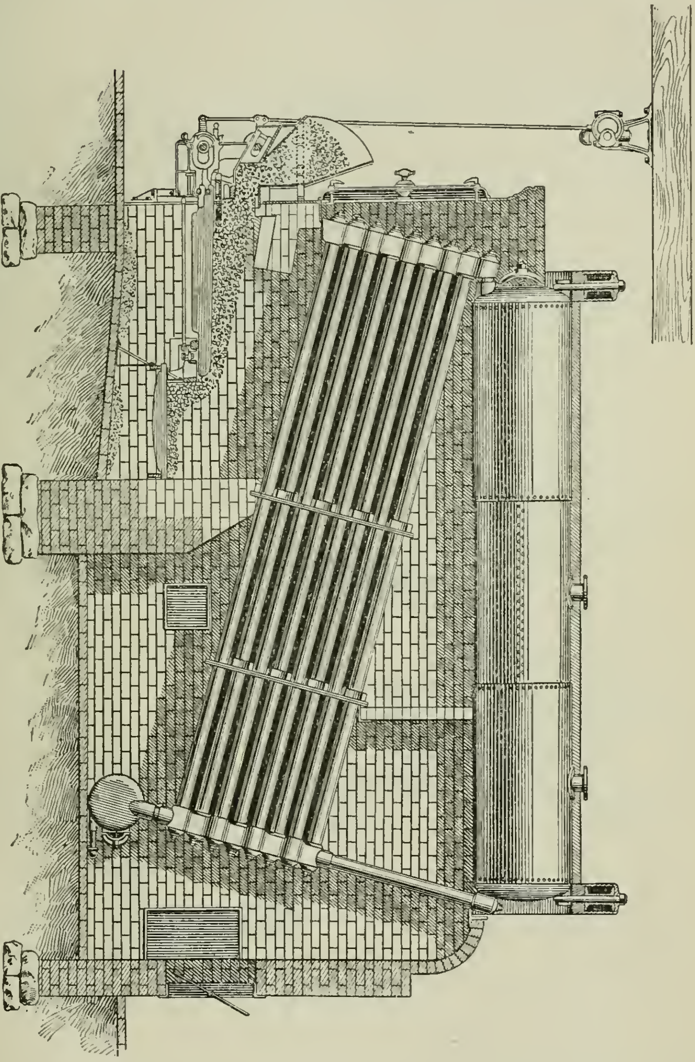

FIG. 6.—The Vicars' automatic mechanical stoker, as applied to Babcock & Wilcox or other types of externally fired boilers.

when one plunger of each pair is going down its partner is coming back. Each shaft has a ratchet wheel keyed on its end and a loose vibrating arm carrying a pawl. A cam can be set so as to permit the pawl to engage the ratchet teeth through

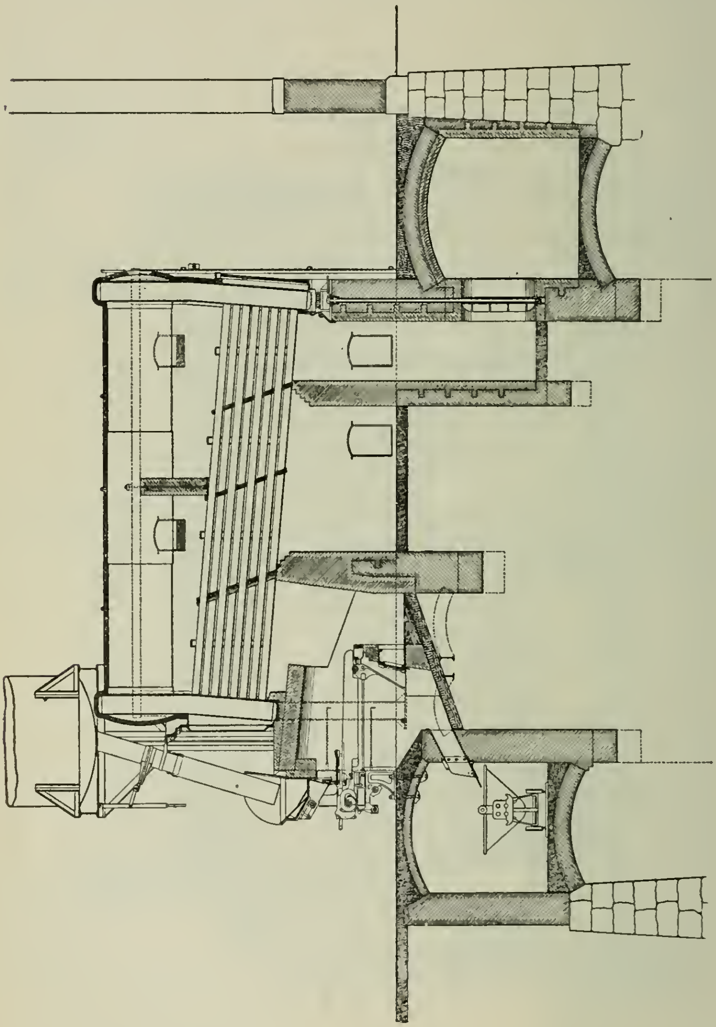

Fig. 7.

the entire vibration or any portion thereof down to zero. Thus, the plungers can be operated at any desired speed, or not at all, simply by adjusting these cams to notches provided for the purpose, and the amount of coal fed through each chute can be nicely regulated.

Fig. 4 is a rear view of the same stoker. The coal comes down the chutes on to the dead-plate, which is stationary, and forms the floor of what might be termed a retort or reverberatory furnace, where the volatile and smoke-producing parts of the fuel are distilled out and pass back into the hot part of the fire, where they are entirely burned and their own heat value is utilized. This coal is gradually pushed forward onto the grate bars. These grate bars have a peculiar, variable and perfectly governable motion. They all move forward into the furnace together, any amount required, from zero to about 4 inches. Then one alternate half of them remains at rest while the other half is drawn back. Then this half remains while the first half is drawn back. Then all move forward together again, and so the cycle goes on, the result being that the coal is slowly moved further and further into the furnace, while the ash, clinker and any unconsumed coal are discharged over the ends into the flues of internally-fired boilers, or upon a fixed grate of externally-fired boilers, where the combustion is completed.

Returning now to *Fig. 3*, we can examine the means of operating the grate bars. There is a vibrating arm, pawl, ratchet wheel and cam for determining the arc through which the pawl shall move the ratchet wheel, similar to the ones for operating the plungers. The shaft has four single teeth, which engage with single teeth in the four sliding frames, the inner two of which operate half of the alternate grate bars, and the outer two the other half, by means of two cross-trees. The inner sliding frames have no tooth on the top, while the top tooth of the outer ones is on a block, which can be held by a pawl in any position required to vary the forward movement of the bars from nothing to the maximum.

We thus see that the amount of coal which can be pushed down upon the dead-plate is variable, from nothing to the maximum, while at the same time the speed and distance that this coal can be moved forward through the furnace is variable, from nothing to the maximum, and that these regulations are independent of each other and distinct for each furnace, so that any required condition of thickness of bed of fuel and of speed of traverse can be maintained with the utmost regularity, without inrushes of cold air or any disturbance of the fuel.

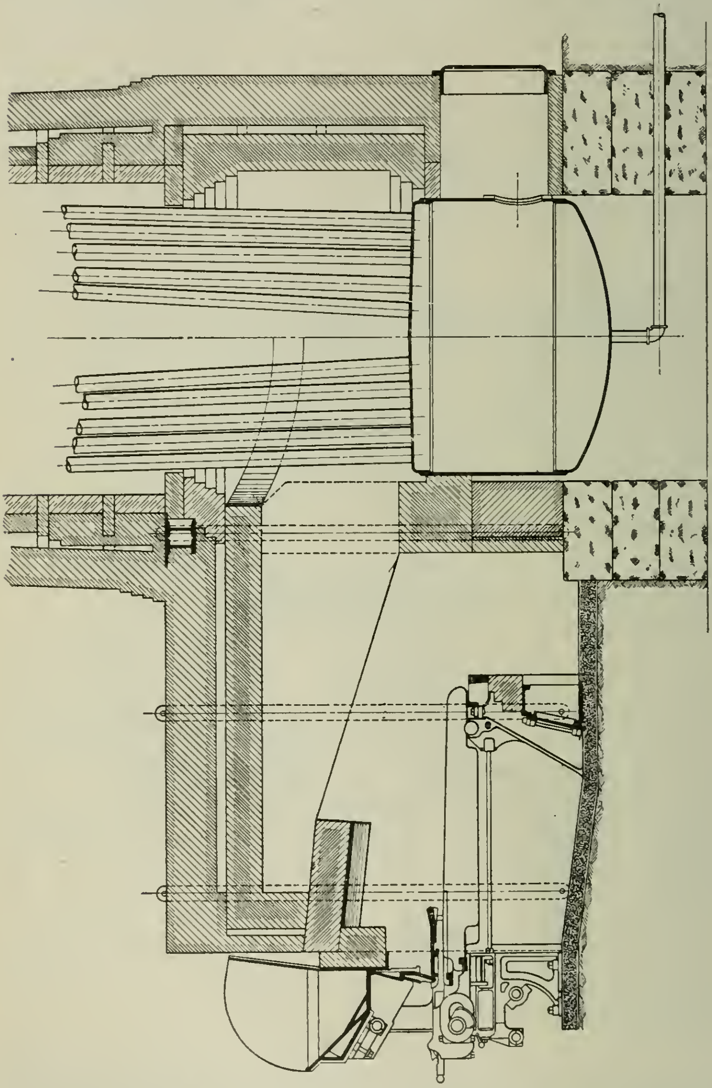

Fig. 8.

Between each chute is a full-sized fire door, which can be let down flush with the dead-plate, and the furnace operated by hand and raked and sliced just as in ordinary hand practice. A readily opened peep door is placed directly over each fire door.

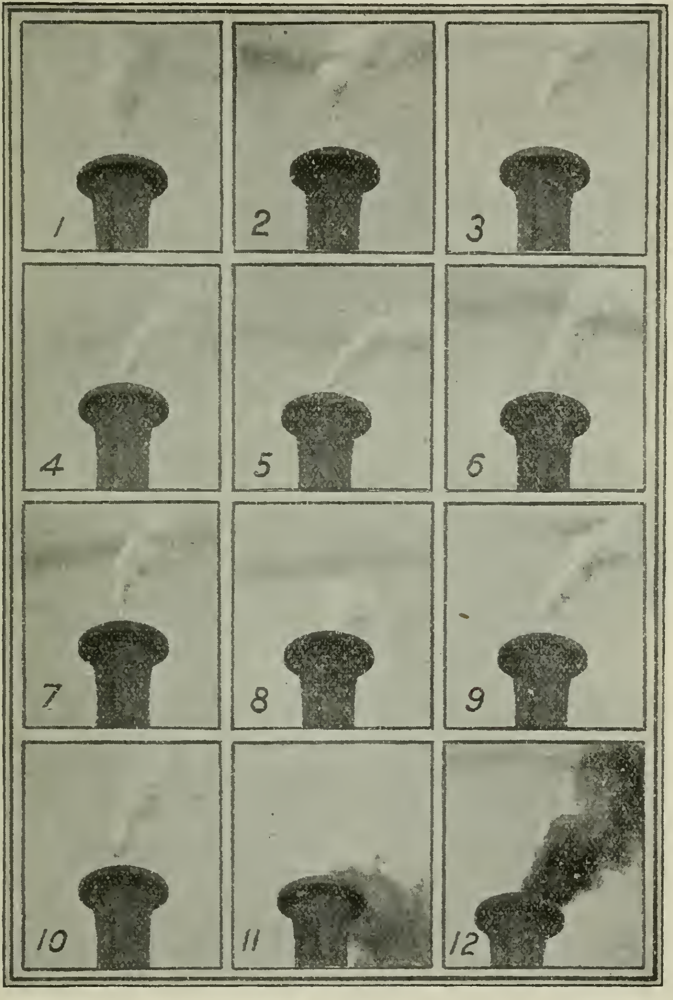

FIG. 9.

Fig. 5 is a sectional diagram of the stoker applied in corrugated flues.

Fig. 6 shows the stoker as applied to externally-fired boilers, with the fixed grate at the back, already referred to. The height and length of the fire-brick arch forming the retort for the fresh coal are varied to suit the kind of coal used.

Fig. 7 shows the stoker as applied in a large plant of externally-fired water-tube boilers, with the arrangement for handling the coal and ashes. The coal is dumped from the cars overhead into a tank over each hopper, and is let down, as required, by opening a slide in the pipe, while the ashes are raked down into the hand-car underneath.

Fig. 8 shows the stoker as applied to the external furnace of a vertical boiler.

Fig. 9 shows a number of photographic views of our foundry chimney-top taken at intervals of about two and one-half minutes when we were burning about 35 pounds of bituminous slack per square foot of grate per hour and developing over 200 horse-power. Nos. 1 to 10 show the results with the stoker working under the usual conditions, the only thing visible being the exhaust steam from the engine. Nos. 11 and 12 show the smoking possibilities of the fuel, the fires being then stirred and fuel added by hand, with the immediate and pronounced emission of smoke, as shown.

THE RONEY MECHANICAL STOKER.*

Mr. William R. Roney [Baltimore, Md.]:—Mechanical stoking in this country has increased so rapidly during the last ten years, that it seems unnecessary to refer to the advantages which a good mechanical stoker possesses over any form of hand-fired furnace, for the smokeless and economical burning of bituminous coal. As an advocate of mechanical stoking, I was pleased to note that the gentlemen who took part in the discussion of the smoke nuisance at the April and May meetings of the Institute, almost unanimously recognized this fact.

This discussion has also emphasized another fact, viz.: that there is no mystery in smoke prevention. It is only a question of intelligent engineering. The problem of smoke or no smoke is simply that of *bad vs. good engineering,* and the recognition of four well-known requirements for complete or smokeless combustion. I referred to them in my remarks at the April meeting, and will venture to repeat. They are:

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* Manufactured by Westinghouse, Church, Kerr & Co., New York.

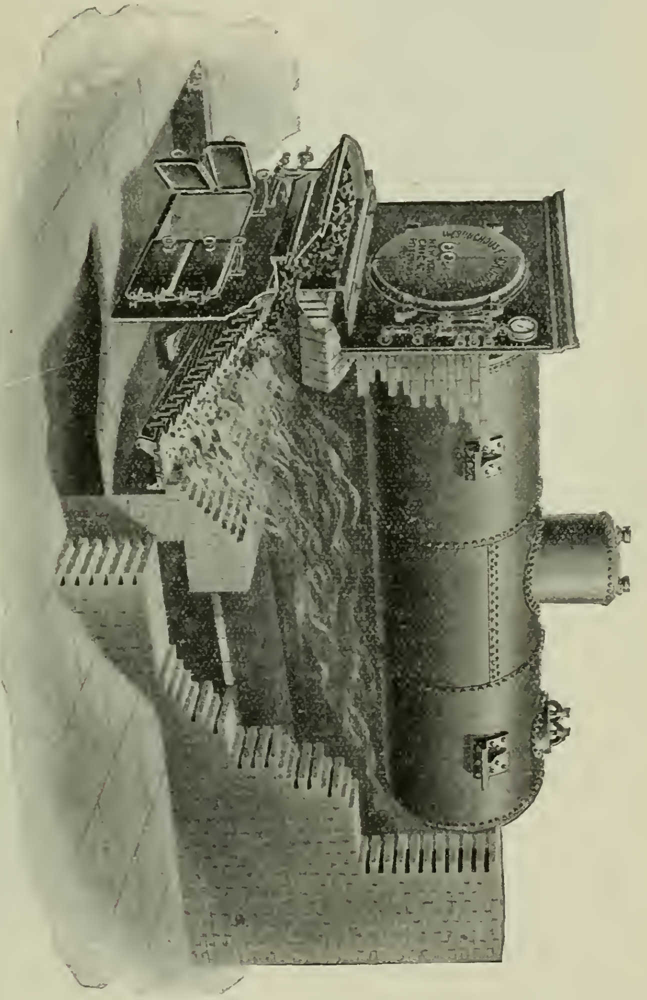


FIG 1.—The Roney mechanical stoker and smokeless furnace as applied to a horizontal return tubular boiler.

(1) Sufficient air to supply necessary oxygen.

(2) A thorough mingling of the oxygen with the volatile gases.

(3) A constant high temperature of air and gases.

(4) A uniform supply of fuel, regulated according to the demands for heat for steam making or other purposes.

To maintain all these conditions is practically impossible with a hand-fired furnace and the average fireman, but with a good mechanical stoker and a fireman of ordinary intelligence, it can be accomplished, and bituminous coal burned without smoke, and with a saving in fuel and labor which will pay good interest on the investment.

In considering the subject of mechanical stoking, the question naturally arises: How should a stoker be constructed, to meet all the varied conditions, or, in other words, what should be the characteristics of the ideal stoker? I would answer:

It should combine simplicity of construction and operation with efficiency, smokelessness, mechanical durability and large capacity, when necessary. It should work automatically, supplying the coal to the furnace as fast as may be required, and maintaining a uniform fire on the grate. It should be so constructed as to permit free passage through the grates of a large amount of air when required, and this should be accomplished without the aid of a slice bar. It should be so constructed as to make possible the easy application of a system of coal- and ash-handling machinery, for the further reduction of labor. It should discharge the ash and clinker quickly and easily, and without the admission of cold air to the furnace. It should be so constructed that the coal magazines and all the mechanism for feeding the coal shall be entirely outside the furnace, and where they will be unaffected by the intense heat. It should be capable of burning successfully all grades of bituminous, semi-bituminous, lignite and anthracite coals. The grate should be easily accessible from above and below, and so arranged that every part can be seen at all times, and the condition of the fire upon the grate ascertained without opening the firing doors. It should be so constructed that repairs can be reduced to a minimum, and worn-out parts be replaced without disturbing the remainder. It must be so simple as to be within the comprehension of the most ordinary mind, and yet, at the same time, in reality, compete with the

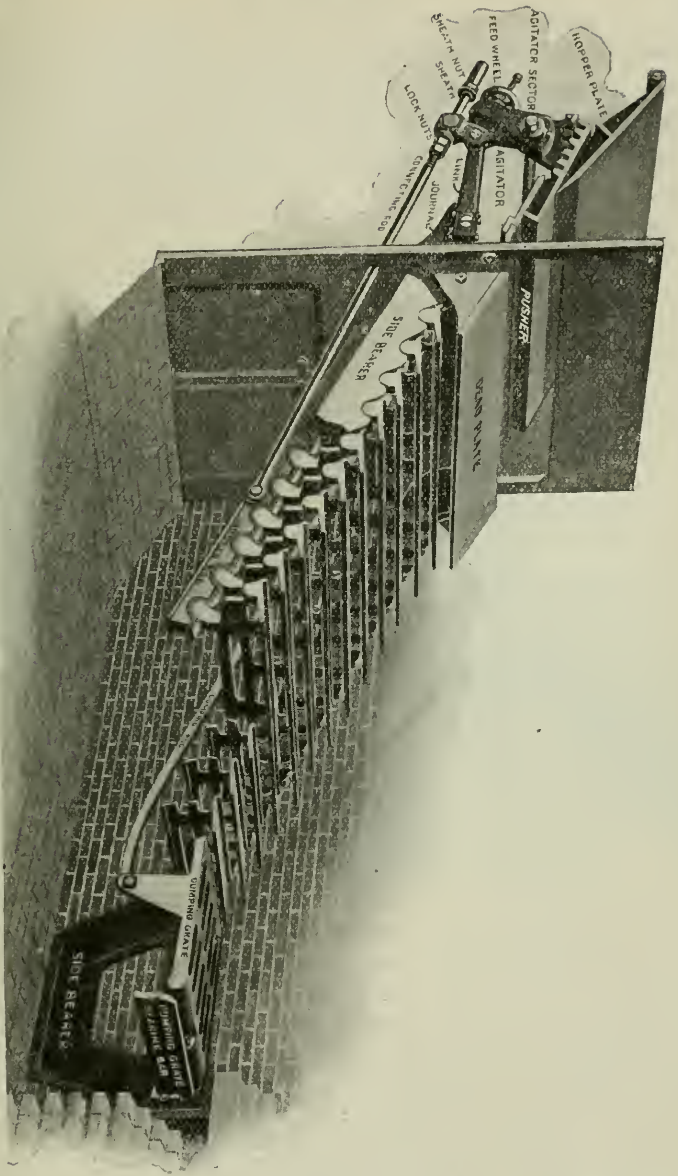


FIG. 2.—Sectional perspective of the Roney mechanical stoker.

work of a skilled hand-fireman, and do it with the accuracy of a machine, which will never "get tired" and never "strike."

It was with some such ideal stoker in mind, and with a conviction that this ideal had not yet been realized, that the speaker undertook some years ago to design a mechanical stoker adapted to the types of boilers and kinds of coal most generally used in this country. How well he succeeded, modesty forbids my saying, but with the assistance of a few lantern slides, I will endeavor to explain to you its construction and operation, that you may judge as to the success attained.

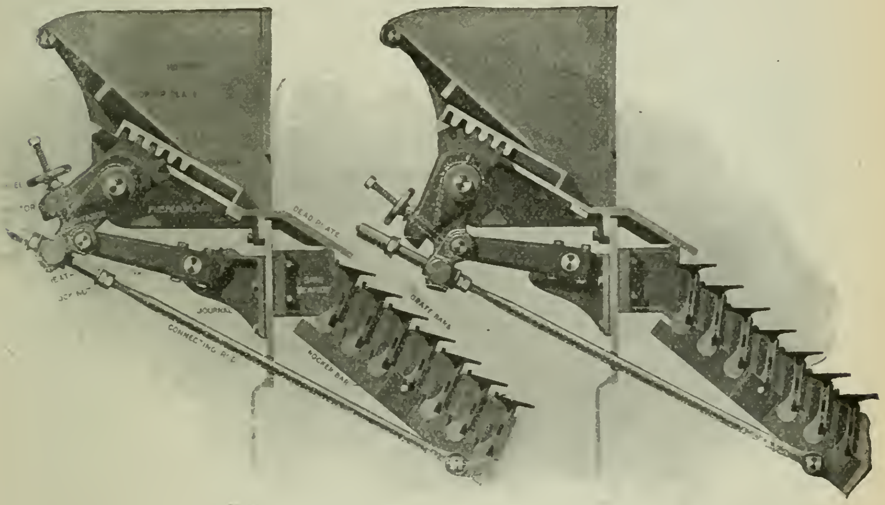
According to the *Bulletin*, announcing this meeting, we, who address you, are expected to make "a statement of claims for efficiency." I feel that this is rather a difficult thing to do —not on account of any lack of efficiency in the apparatus which I have the privilege of describing to you to-night, as I trust will be evident, but on account of natural diffidence and a reluctance, which even stoker inventors may sometimes possess, to appear to "blow my own trumpet." Neither would I wish, when explaining the merits of my own apparatus, to appear in any way to detract from the merits of other mechanical stokers. I will, therefore, paraphrase a well-known remark regarding Kentucky's noted beverage by saying: "All stokers are good, but some stokers are better."

Mr. Roney then explained by means of lantern slides the construction and operation of the Roney Mechanical Stoker, and exhibited views of several large boiler plants equipped with this stoker. The most notable was that of the steam plant at Spreckels' Sugar Refinery, Philadelphia, containing 9,000 horse-power of Babcock & Wilcox boilers equipped with Roney stokers and coal- and ash-handling machinery. This is the largest single plant of boilers in the world thus equipped. The coal is brought by trainload, crushed and elevated to the storage bunkers at the top of the boiler house, from whence it flows by gravity through chutes to the stoker hoppers. The ash and cinder from all the boilers is discharged by gravity into the cellar and thence elevated to an ash-bin, from which it is discharged into cars for removal. So complete is the system, that from the time the coal is dumped into the crushers until the ash is delivered into the cars for removal no manual labor is required. The economy of labor and fuel is remarkable.

The last lantern slide shown was that of two steam pressure diagrams, taken at the Baltimore Electric Refining Works, before and after Roney stokers were installed, and illustrated vividly the great advantage of mechanical stoking over hand-firing in maintaining a uniform boiler pressure under sudden and extreme variations in the demand for steam.

The following is a detailed description of the construction and operation of this stoker:

"The Roney Mechanical Stoker and Smokeless Furnace" is shown in *Fig. 1* applied to a horizontal return tubular boiler, and *Figs. 2, 3* and *4* show the details of the latest construction, and the positions of the grate bars and feeding mechanism when in operation. From these illustrations it will be seen that it is a simple apparatus which receives the fuel in bulk, and without further handling, feeds it continuously and at any desired rate to the furnace; burns the combustible portion and deposits the ash and cinder in the ash-pit ready for removal.



INCLINED POSITION. STEPPED POSITION.

FIG. 3.—Details of feed and grate movement.

In the bottom of the hopper is located a sliding pusher (see *Figs. 2* and *3*), actuated by a sector, which engages a rack on the under side of the pusher, and by which it is given a reciprocatory motion, which gradually feeds the coal over the dead-plate and onto the grate. The grate consists of horizontal flat-surfaced bars, extending from side to side of the furnace, carried on side bearers, extending from the throat of the hopper to the rear of the ash-pit, and inclined at an angle of 27° from the horizontal. In the wider furnaces, two sets of grate bars are placed side by side, provided with independent actuating connections. The bars in each set are coupled together by a "rocker bar," the notches of which engage with a lug on the lower rib of each grate bar. A variable reciprocating motion being given to the rocker bar through a connecting rod, the grate bars rock in unison, now forming a series of steps and now approximating to an inclined plane, with their tops overlapping like the shingles on a roof (*Fig. 3*). The depending webs of the grate bars are perforated with longitudinal slots, so placed that the condition of the fire can be seen at all times and free access had to all parts of the grate without the opening of doors. These slots also serve an important purpose in furnishing an abundant supply of air for combustion. The sectional perspective cut, *Fig. 2*, illustrates clearly the form of the grate and the advantages of this construction. When the grate bars rock forward into the inclined position, the burning coal tends to work down in a body. But before it can move too far, the bars rock back to the stepped position, checking the downward motion, breaking up the bed of fuel and admitting a free volume of air through the fire. This alternate starting and checking motion keeps the fire constantly stirred and opened up from underneath, and finally lands the cinder and ash on the dumping grate, from which it is discharged into the ash-pit by releasing the dumping rod—the work of but half a minute. All this is accomplished without opening the fire doors.

The actuating mechanism is simple, all motion being taken from one driving shaft, extending across the boiler front and driven by a small engine. The power required has been found by test to be *less than one-quarter horse-power* for each 150 horse-power boiler. Motion is communicated to the "agitator" by means of an eccentric or a crank and link, *Fig. 3*, and thence to the "agitator-sector" and rack. Through the eye of the agitator-sector passes a stud screwed into the agitator, on which stud is a feed-wheel, used to regulate the motion of the agitator-sector and pusher, the position of the feed-wheel on the stud determining the length of stroke of the pusher. The rocking of the grate bars is in like manner regulated by the position of the "sheath-nut" and "lock-nuts" on the "connecting-rod." By these two simple adjustments, within the comprehension of the ordinary fireman, the whole action of the stoker is controlled, and the fires forced, checked or banked at will.

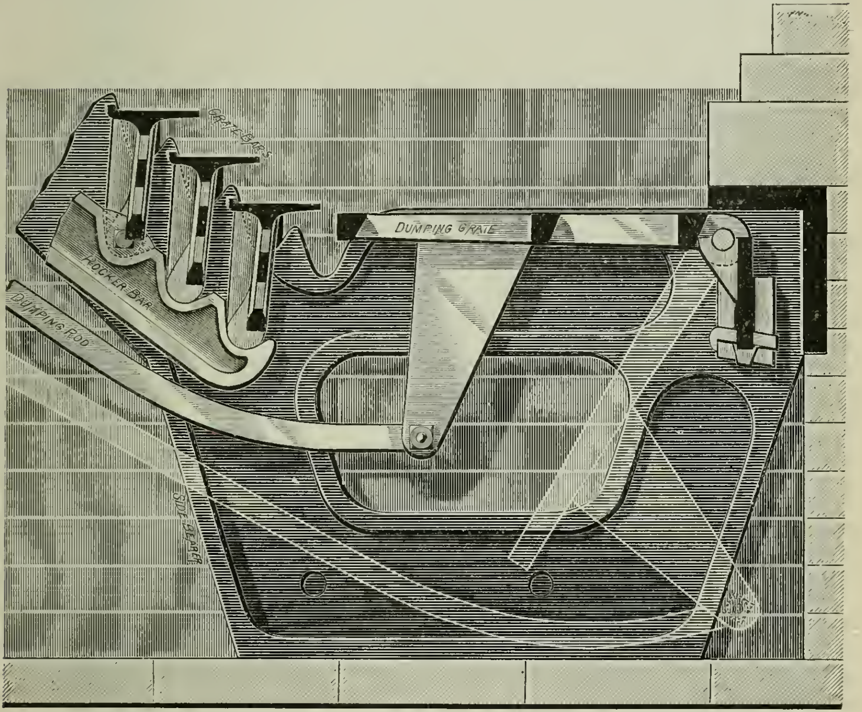


FIG. 4.—Details of dumping grate. The shaded outline shows position of grate when dropped.

A coking arch of fire-brick is sprung across the furnace (see *Fig. 1*), covering the upper part of the grate, forming a reverberatory furnace and gas-producer, whose action is to coke the fresh fuel and release its gases, which, mingling with heated air and steam supplied in small streams through the perforated tile above the dead-plate, are quickly burned in the large combustion chamber above the bed of incandescent coke on the lower part of the grate. This method of supplying the coal at the front and coolest portion of the furnace and gradually advancing it towards the hottest portion, presents conditions most favorable for complete and economical combustion, and in operation closely resembles a large Argand burner in the ease with which it is regulated and its smokeless combustion of the hydrocarbons of the coal.

This stoker burns successfully and smokelessly all kinds of bituminous, semi-bituminous, lignite and anthracite coals; the complete regulation of the feed and grate motion, together with the method just described, of supplying heated air and steam, adapting it to all the various coals used for steam making. Waste products, such as tan-bark, saw-dust, cotton-seed hulls and coke-dust are frequently burned in this stoker.

THE BABCOCK & WILCOX STOKER.*

THE SECRETARY:—"The Babcock & Wilcox Stoker," as shown by the accompanying cuts,† is an endless chain grate, mounted in frames carried on wheels, so that the stoker can be moved in or out without interfering with the brickwork.

The power for moving the grate and feeding the stoker thereon is furnished by an independent engine for each stoker, and is delivered by a ratchet and lever to a worm wheel. The coal is furnished either from a hopper overhead, or shoveled by hand in the ordinary way, and the coal feed is regulated by means of a gauge at the rear of the hopper, which can be raised or lowered according as a thick or thin fire is desired.

The grate consists of links, which can be readily removed should it become necessary to do so, and can be removed and replaced in from ten to fifteen minutes; but experience has shown that it is seldom necessary.

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* Manufactured by the Babcock & Wilcox Company, New York.

† For the use of these illustrations the *Journal* is indebted to the *Transactions* Am. Society of Mechanical Engineers.

The stoker is driven by the front sprockets, and is therefore pushed forward rather than pulled from the rear. There is a damper in the back, at the rear of the stoker carriage, for the purpose of preventing circulation of air between the stoker and the bridge wall.

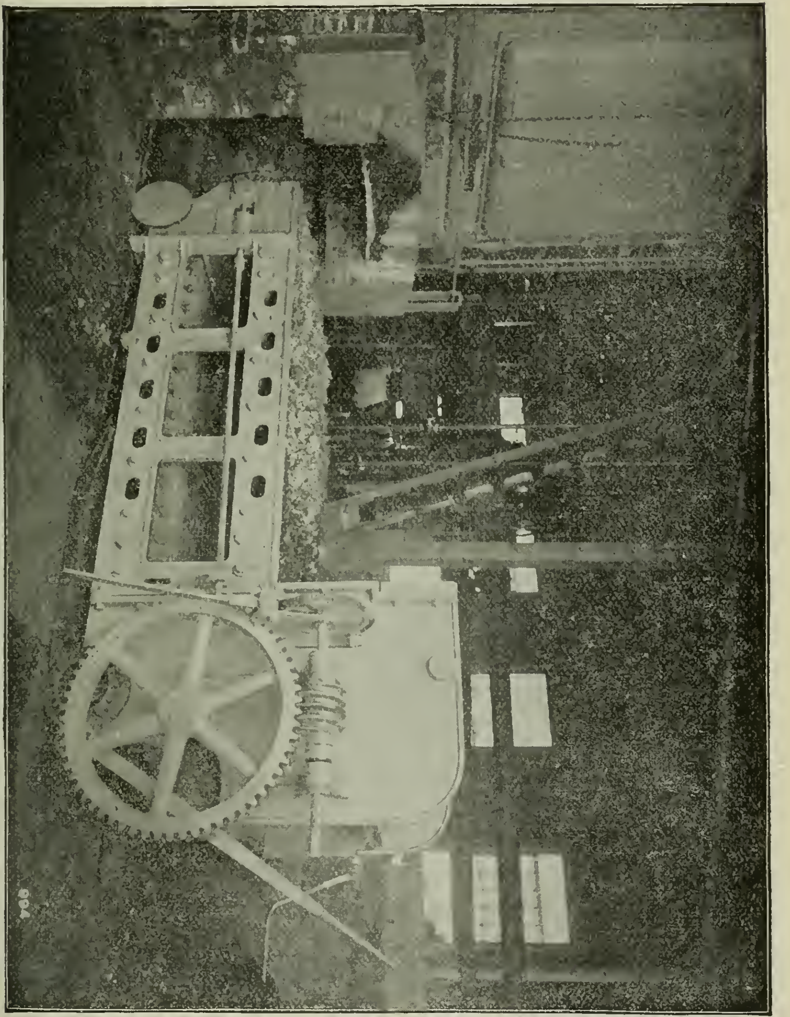

FIG. 1.—Babcock & Wilcox stoker removed from furnace.

When it is run in accordance with directions given by the manufacturer, the Babcock & Wilcox chain-grate stoker will give no more smoke from bituminous coal than a flat grate will give from anthracite coal.

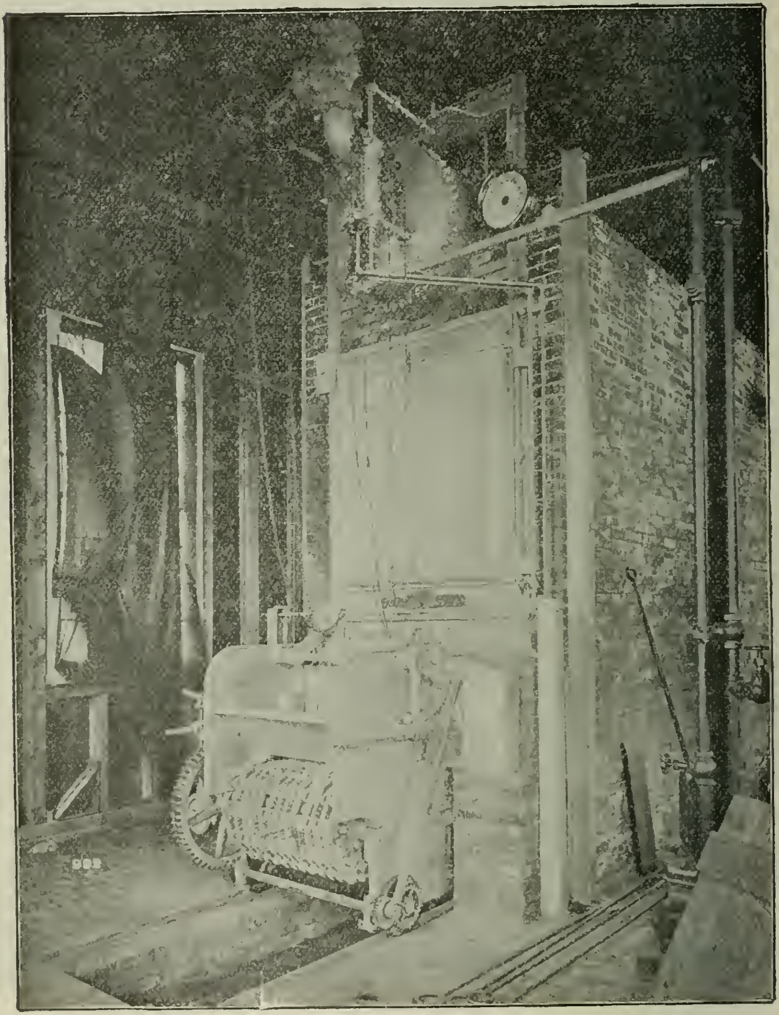

FIG. 2.—Front of Babcock & Wilcox chain-grate stoker.

As a labor-saving device, the stoker becomes valuable just as soon as the number of boilers in the plant require more than one fireman. Its adoption in small plants, for the purpose of reducing labor, is not recommended.

Another advantage of the stoker is its ability to burn the low grades of fuel that cannot be burned on the ordinary grates. In places located a long distance from mines, where freight is a very large percentage of the cost of coal, this argu-

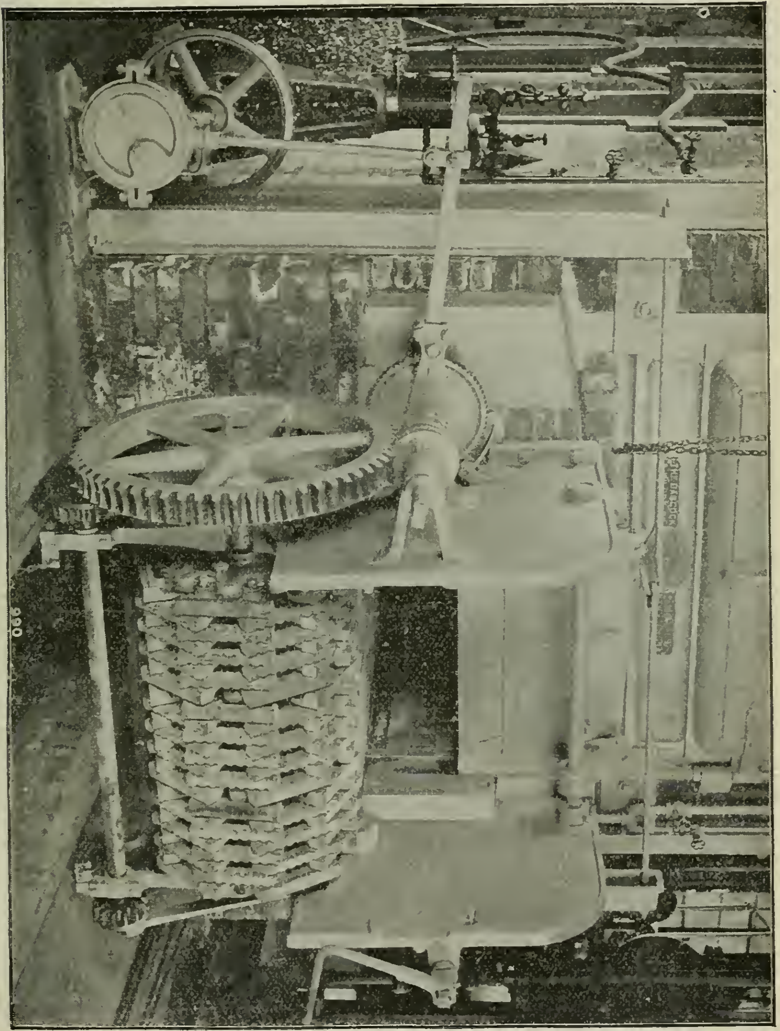

FIG. 3.—Driving mechanism of Babcock & Wilcox stoker.

ment will not have much weight; but in places near the mines, where slack or low grades of fuel can be obtained at a small percentage of the cost of run-of-mine coal, the argument holds good, and the stoker will burn it as readily and with good economy.

The following conditions are important when using the Babcock & Wilcox chain grate:

Draft Conditions.—To get the best results from a mechanical stoker, a high rate of combustion must be maintained. This means that the draft must be good, and in all cases it will require not less than ¾ of an inch of water, measured in the furnace; and if the coal is of a very low calorific value, this pressure should be increased.

Fuel.—The chain-grate stoker, as designed by the Babcock & Wilcox Company, is adopted for burning bituminous coal *only*, and cannot be used with fuel that does not ignite freely.

The stoker is made in sizes ranging from 46 inches wide to 116 inches, length ranging from 6 to 8 feet. (From data supplied by the manufacturers and illustrated by a working model.)

THE AMERICAN STOKER.*

MR. C. H. BIERBAUM [Dayton, O.]:—From the previous discussions on the subject of smoke prevention, there seem to have been evolved these general concurrent ideas: that the proper way in which to effect an abatement of the present smoke nuisance is to burn the coal in such a manner that no smoke can occur; and that the great numbers of so-called smoke consumers with which the Patent Office has been flooded and the public beguiled are more or less an economic failure.

The greatest loss of heat existing in all ordinary furnace practice is that which is carried off by the chimney gases, and the actual losses due to incomplete combustion are so small, that only in cases of bad management do they become of sufficient consequence to deserve any consideration as regards economy. The fallacy of the general notions that a clear stack signifies economy, and that a smoky stack means wastefulness, is being appreciated more and more. The principal loss from the incomplete combustion of gases is not indicated by the appearance of the chimney mouth, but is due to the escape of invisible gases, and the visible smoke formation is a rather insignificant item of loss. The experiments of Professor Tatlock, Scheurer-Kestner, and those made at Sibley College, all tend to show conclusively that the average heat losses due to the formation of smoke do not exceed three-quarters of 1 per cent.

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* Manufactured by the American Stoker Company, Dayton, O.

Smoke proper is always the result of the incomplete combustion of hydrocarbons, whatever the fuels may be from which they have been distilled. Coke and charcoal, for example, burn without smoke, since in the process of manufacture they have already been deprived of their respective gaseous constituents.

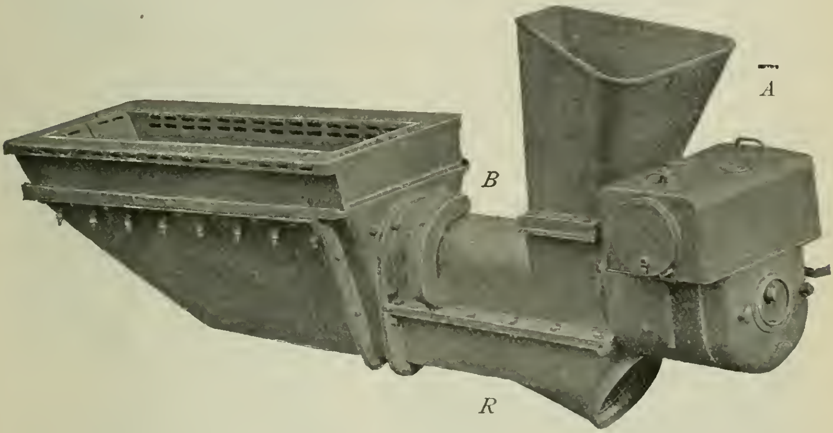

FIG. 1.—The American stoker.

The common kerosene lamp may be taken as the simplest smokeless furnace, designed specially for the burning of hydrocarbons—a furnace in which complete combustion occurs. The lamp, under proper conditions, burns with a bright, clear flame, free from smoke, with a large excess of the theoretical amount of air necessary for complete combustion.

Now remove the chimney and you have a smoky flame, notwithstanding the still freer supply of air. In fact, the smoke is due to an excessive admixture of cold air, operating to cool the body of the flame below the temperature necessary for the ignition of carbon. Now take a broken chimney with a small hole in the side at a point of its greatest diameter. If the hole be small enough, no appreciable effect may be apparent, but let a slight draft strike the chimney in a direction so as to enter the opening, and a smoky flame is the result. This is due to two conditions: A too limited supply of air from below, and the influx of air from the side, acting to cool the combustion chamber.

Thus, the two requisites for preventing the formation of smoke are these: To supply an adequate amount of free oxygen; and, secondly, to have the gases subjected to a temperature at which carbon ignites.

A number of interesting experiments have been made with a view of determining this temperature, and it is generally considered that it is somewhat above 3,200° F. The simplest experiment is that of taking an extremely fine platinum wire and thrusting it into the lower edge of the luminous zone of the flame, where the ignition of carbon begins, and the wire will be fused. The temperature of ignition of carbon must therefore be somewhat higher than the figure given for the fusion point of platinum, 3,227° F.

The heat losses in ordinary furnace practice may be classified under three heads: Radiation, incomplete combustion, and those due to an excessive dilution of furnace gases. The losses due to radiation are relatively small, and deserve but little more than due precaution. The entire losses due to incomplete combustion may be sub-divided into three classes: The loss due to the escape of an invisible combustible gas or gases, those due to the loss of the visible smoke, and the fuel loss in the ash. Those due to an excessive dilution are well illustrated by the operation of a plant with a moderately clean stack, to which the proprietor and neighborhood had ascribed good economy, and which showed, upon a careful investigation, that for a period of twelve hours an average of 35 per cent. of the total heat generated in the furnace was carried off by the chimney gases, owing to an excessive use of air, which had largely been contributed by a patented air flue discharging at the bridge wall. In spite of this sacrifice in economy, the stack still, at times of firing, poured out large volumes of smoke.

An error that is commonly made is that of calculating the heat losses due to the escape of invisible combustible gases, as carbon monoxide (CO). This is a colorless gas, and has, *per se*, no relation with the visible smoke formation, notwithstanding that attempts have been made to compile tables giving the probable amounts of CO corresponding to certain densities of smoke. CO is always the product of dissociation, and its percentage is a direct function of the absolute temperature and pressure under which it was formed. That is, if we take a volume of carbon dioxide (CO_2), and subject it to a high temperature, the amount of carbon dioxide converted into carbon monoxide and free oxygen is a direct function of the absolute temperature and pressure. An increase of tem-

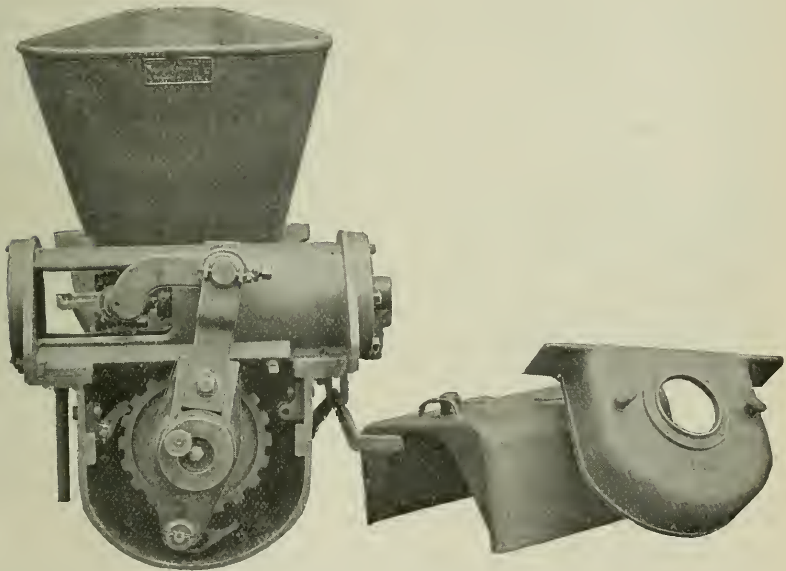

FIG. 2.—The Independent steam motor (American stoker).

perature tends to increase, and an increase of pressure tends to decrease, the dissociation. It is quite unlikely that CO should ever be formed in our ordinary boiler furnace in any appreciable amount—even a trace of it is improbable when any free oxygen is present, and the temperature is above the ignition point of CO. In our flue gases we always find from 4 to 10 per cent. of free oxygen. One fact concerning this matter, which is often not taken into consideration, or perhaps not generally known, is this, that ethylene, acetylene and other hydrocarbons are quite readily absorbed by either the ammoniacal or the hydrochloric acid solutions of cuprous chloride, the usual reagents for the absorption of CO. In alluding to this fact, Dr. Hempel, probably the best living authority on flue-gas analysis, says: "The disregard of which, of course, must lead to wholly useless results." And it is more than likely that the disregard of the foregoing fact has led to the erroneous association of carbon monoxide with visible smoke. Nevertheless, the presence of a gas or gases which are absorbed by the cuprous chloride, gives us direct evidence of the possible escape of combustible gases during the periods of dense smoke formation, and therefore the heat losses ordinarily attributed to the existence of CO, and calculated as such, should be at least doubled, since the calorific value of a mixture of these hydrocarbons is probably more than twice that of carbon monoxide.

By the heat of the fire the hydrocarbons are either liberated or volatilized, and, in the gaseous state, in the presence of free oxygen and heat, they are broken up. Hydrogen, the gaseous and more inflammable constituent, ignites readily at a lower temperature than carbon. Now, if the combustion of the hydrogen does not produce a temperature sufficiently high for the ignition of the carbon also, the carbon then is permitted to pass off as soot. Take, for example, a single molecule of ethylene gas (C_2H_4). The 4 atoms of hydrogen combine with 2 of oxygen to form 2 molecules of water, and the 2 atoms of carbon remaining free are carried off suspended in the current of chimney gases. The reasons for the gases not always reaching the necessary temperature are quite apparent: excessive dilution of the gases, a too rapid dissipation of heat by either radiation or conduction, and ofttimes by the presence of aqueous vapor in too large an amount. This vapor of water, or steam, never aids the combustion, and can only serve to produce a two-fold loss, in that it reduces the temperature below the ignition point of carbon; and, secondly, increases the volume and the aggregate specific heat of the gases, and thus augments the heat losses correspondingly. Cases are on record where steam jets are claimed to have produced phenomenal results. Any advantages from this cause can only have been of a mechanical nature, either by agitating the products of combustion where the combustion chamber was too small and no intermingling of the gases could otherwise be effected, or by its presence tending to precipitate the soot to the rear of the bridge wall, or somewhere in its course, and thus reducing the actual amount discharged by the stack.

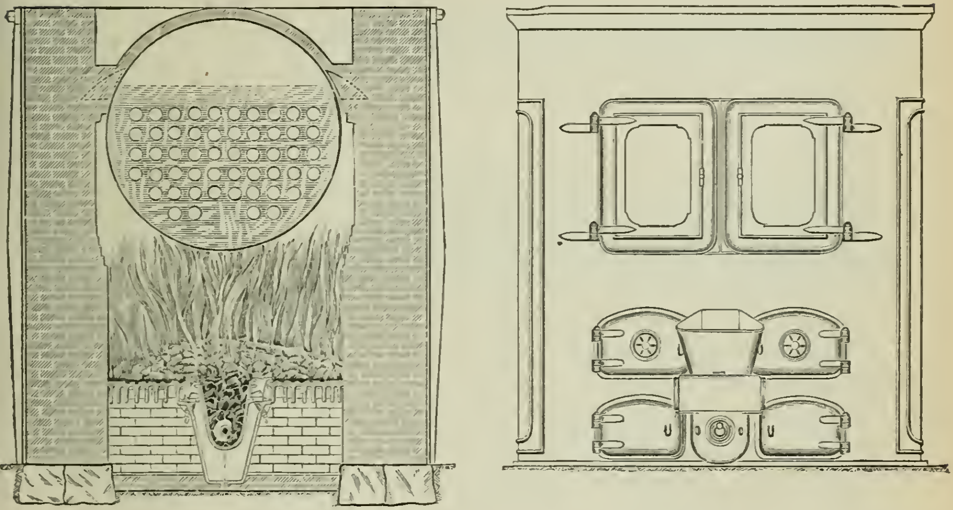

FIG. 3. Front view and cross-section (American stoker).

The introduction of heated air above the fire for the purpose of perfecting the combustion can likewise never be made an entire success, since the temperature of this heated air must not only be equal to that of incandescent carbon, but must greatly exceed it, in order that after mixing with the products of combustion a resulting temperature of this mixture shall be obtained sufficiently high to ignite the carbon. But since all our materials, suitable for the construction of air ducts sufficiently refractory to withstand this intense heat, are likewise extremely poor conductors of heat, a secondary furnace equal to or still larger than the original one would be required for heating the necessary air, thus simply transferring the problem of smoke prevention from the primary to the secondary furnace.

I will now invite your attention to the construction and operative features of the "American Stoker," an apparatus successfully employed for effecting smokeless combustion.

Fig. 1 shows the American stoker assembled ready for installation. Immediately beneath the coal hopper (*A*), and communicating with it, is the conveyor chamber (*B*), this in turn communicating with the magazine in direct line with it. A screw conveyor, or worm, is located in the conveyor chamber, and extends nearly the entire length of the magazine. Immediately beneath the conveyor chamber is located the wind-box (*R*), having an opening directly beneath the hopper, the connection for the air pipe. The other end of the wind-box opens into the air space between the magazine and outer casing or envelope. The upper edge of the magazine and envelope are surmounted by tuyere blocks, these tuyere blocks being provided with openings for the discharge of the air. Beneath and in front of the hopper is located the motor for operating the stoker.

Furnaces over 6 feet in width, and too wide for a single stoker, are equipped with the double stoker. This is a combination of two single machines feeding from a common hopper and operated by the same motor. The space on each side of the stoker, between the tuyere blocks and the side walls of the furnace, is occupied by dead-plates, or air-tight grates. The incombustible portion of the coal congeals into a vitrous clinker, accumulating on these dead-grates in lumps quite free from coke. In a twelve-hour test by Prof. W. B. Potter on a battery of six double stokers at the Anheuser-Busch Brewing

Association, St. Louis, it was found that only .93 of 1 per cent. of fixed carbon had been lost in the ash.

Fig. 2.—The motors are simply piston steam engines. The piston rod carries a cross-head, which, by means of suitable connecting links, operates a pawl mechanism, which, in turn, actuates the ratchet wheel mounted on the conveyor shaft.

Fig. 3 shows a general front view and cross-section of a boiler furnace equipped with the American stoker. *Fig. 4* is a longitudinal sectional view of the stoker beneath a tubular boiler.

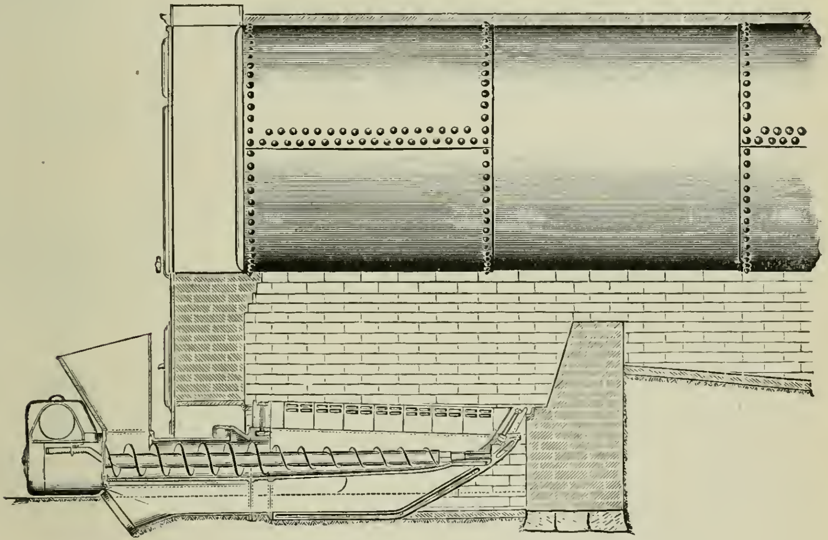

FIG. 4.—The American stoker under tubular boiler.

The coal is fed into the hopper, carried along by the conveyor through the magazine, overflows from it on both sides, and spreads upon the dead-plates the entire width of the furnace. The entire mass of coal above the tuyere blocks, and all of that upon the dead-plates, is ignited, carrying a bed of burning coke from 14 to 18 inches in depth.

The two prerequisites for combining smoke prevention with economy are: A complete combustion of the hydrocarbons, and using the least possible amount of air. It is quite evident that none of the gaseous constituents of the coal can escape perfect combustion under the proper conditions of operation of this stoker. The green coal, being fed from underneath the bed of fire, liberates its hydrocarbons upon coming in contact with the fire. The air, being supplied at this point where the hydrocarbons are evolved, is mixed with them, and this mixture then, in turn, passes through the deep bed of incandescent coal. The economic use of air is due to the method of operation also peculiar to this stoker, in that it carries a bed of coal of unusual depth, the air being supplied from underneath, the volume of which, being furnished by a blower, is kept under perfect control, and the continuous upward feeding of the coal counteracts the natural tendency of holes burning through the fire.

In point of construction it is notable for the fact that no mechanical part of the stoker is subjected to heat, ordinarily the chief cause for objections against stokers.

The wide application of this stoker is no less a feature of interest. Not only has it been successfully used under all types of boilers, but it is likewise equally well adapted and successful in puddling furnaces, heating furnaces, lime-kilns and furnace work generally.

The following series of views, *Fig.* 5 (Nos. 1 to 10), was taken by order of the Cleveland City Council, in order to determine what stoking devices, in use at the Division Street Pumping Station, were practical smoke preventers. Each stack serves four tubular boilers fired with cheap Pittsburgh coal, the three sets of boilers doing the same amount of work. The stack to the left in each view represents the American stoker.

THE WILKINSON AUTOMATIC STOKER.

MR. WILKINSON [Bridgeport, Pa.]:—In calling your attention to the "Wilkinson Mechanical Stoker," it behooves me to say, first, that in its main features of mechanical construction and performance, it differs very little from other forms of stokers; that is, it is provided with a hopper to receive

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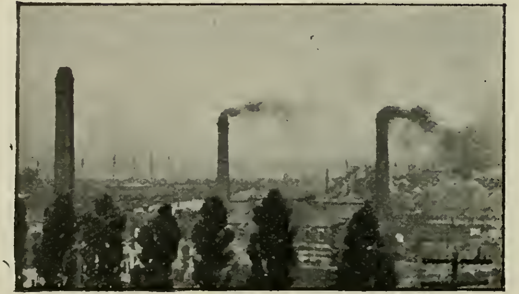
* Manufactured by the Wilkinson Manufacturing Company, Bridgeport, Montgomery County, Pa.

Jour. Frank. Inst., Vol. CXLIV, December, 1897. (*Smoke Prevention.*)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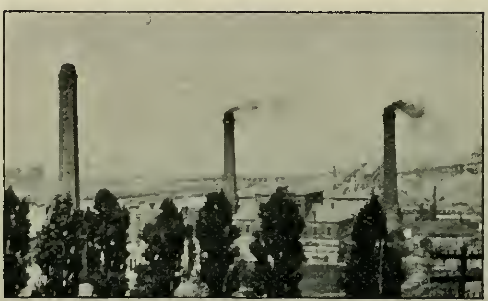
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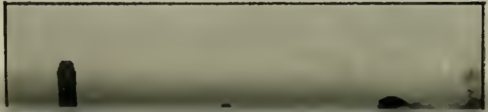
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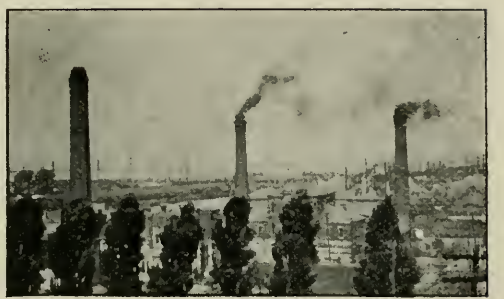
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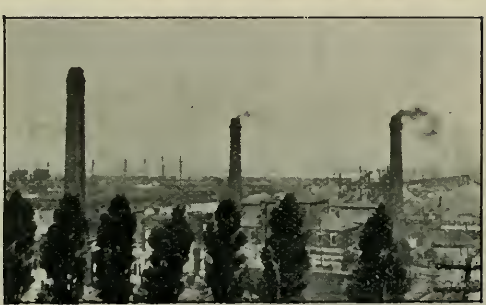
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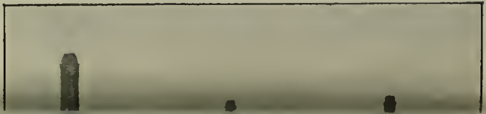
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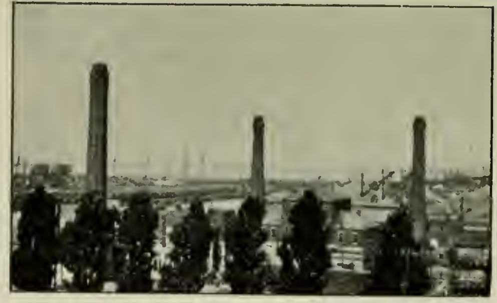

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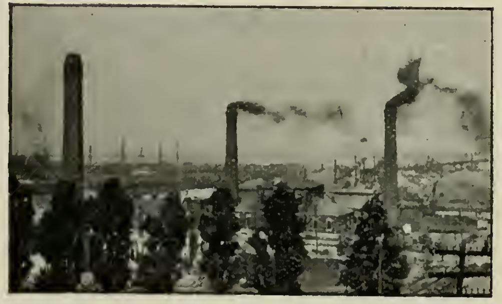

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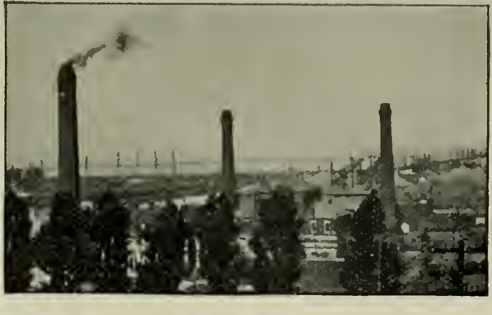

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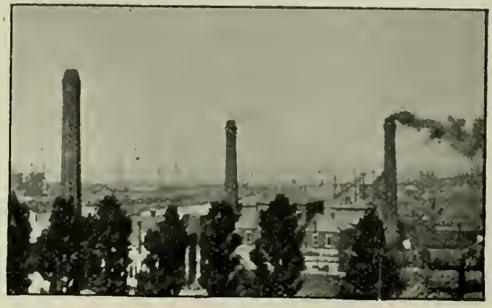


No. 10, 11.04 A.M.

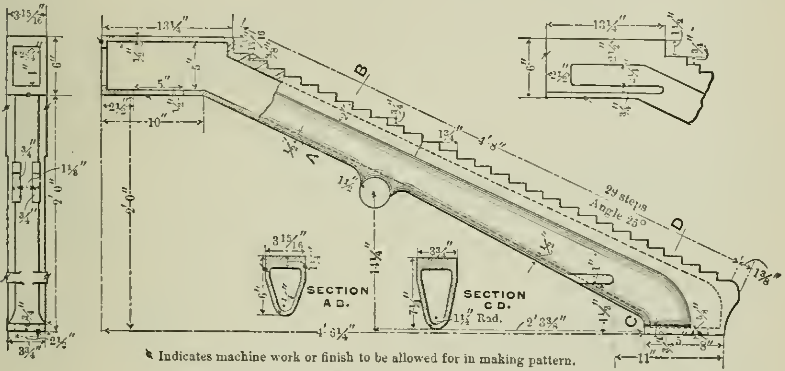
FIG. 5. Stack to left, American Stoker.

the coal, a grate on which to burn the coal. In its system of burning fuel, however, it is not at all like others.

As a device for burning of the cheaper grades of anthracite or bituminous coal, it is particularly efficient.

Having reference to the illustrations,* it will be observed that all that portion of the boiler front below the bottom line of boiler, together with the grate bars, bearer bars, etc., as in ordinary practice, is eliminated from first cost when new installation is considered, or discarded when it is proposed to add the stoker to a boiler in use.

In place of these a stoker front, suited to the purpose, is furnished; and at either side of the furnace, heavy side frames are placed, extending diagonally the whole length of the grate, tying the stoker front securely to the bearer bar or blast box at the back. Suitable projections on the stoker front support the mechanism for moving the grate bars, and admit of securing the coal hopper and blast pipe, as shown.



↖ Indicates machine work or finish to be allowed for in making pattern.

Grate-box of the Wilkinson automatic stoker.

The grate bars are a series of hollow castings approximately of rectangular cross-section, placed side by side, and inclined toward the bottom of furnace, at an angle suited to the repose of the fuel; the upper end (open to admit the blast pipe) projects through and is supported by the stoker front, the lower end sliding on and supported by the bearer bars, as shown. Throughout the inclined length and on the face of each bar is cast a succession of steps, solid on the tread, but through the rise of each step a vent of ample proportion is provided to inject air through the fire to the combustion chamber.

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* For the use of these cuts the *Journal* is indebted to the *Trans.* Am. Society of Mechanical Engineers.

The grate bars are independently connected to the moving mechanism, and by this means an alternate "back and forth" motion is given to the whole series that is constant and uniform.

A pusher, shown resting on the top of the grate bars, is doweled to each alternate bar, and advances and recedes with them, pushing the coal on to the front end of the grate; the continuous "back and forth" motion of the grate bars insuring a uniform thickness of fire; an ample supply of air for any rate of combustion, and an absence of clinker; a slow, but gradual advance of the remaining fuel to the bottom of the grate, thoroughly consumed, in the form of ash, free of carbon, and is deposited on the stationary grate to give off its heat, the same "back and forth" motion of the main grate forcing the accumulated ash off the table grate into the pit, to be removed in the usual manner, or by special appliances.

The mechanism for effecting the entire operation of the stoker consists of a pulley, compound gears, with the necessary levers and shafts. The power required does not exceed one-tenth of 1 horse-power for each stoker.

The blast is saturated steam through nozzles of one-sixteenth of an inch opening, giving an induced current of air of wide range and under complete control of the attendant.

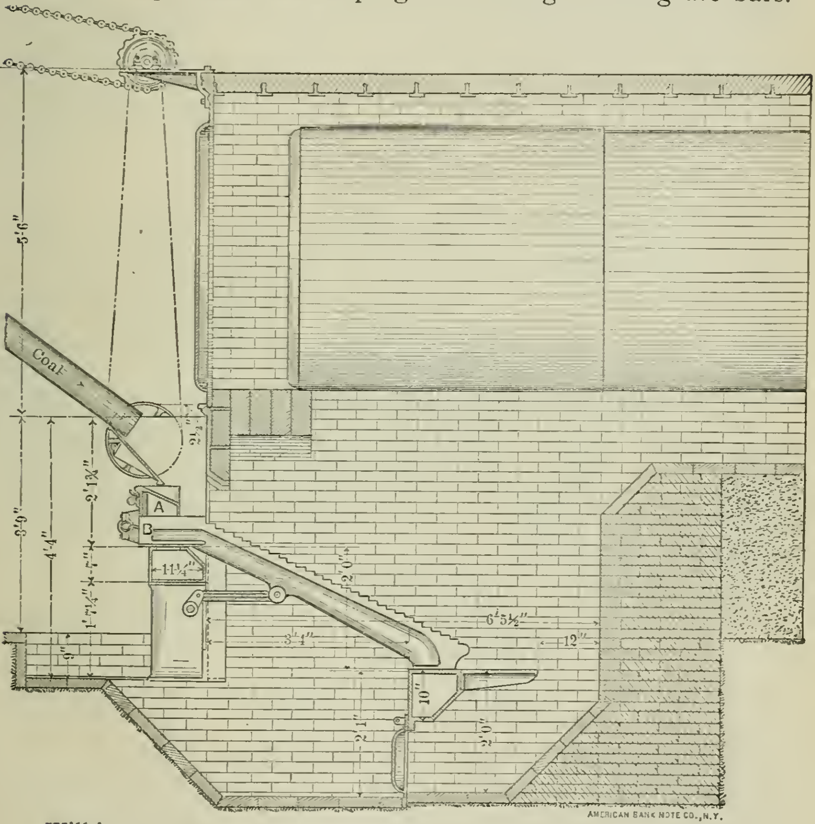
The special features incorporated in this particular stoker are as follows:

(1) The subdivision of the air blast, *i. e.*, every 4 inches of furnace width, which is the width of each grate bar, has twenty-seven tuyere openings, 2½ inches by ⅝ inch, about 1½ square inches area; a furnace 60 inches wide will contain fifteen bars, hence 15 × 27 = 405 miniature blacksmiths' fires, equally divided over the fire bed; aside from this every 4 inches of furnace width is as an independent furnace, having its own mechanism and its own steam jet.

The use of this steam jet has a three-fold purpose:

(1) To induce the air in measured quantities at the will of the attendant, thereby regulating the rate of combustion and consequently the production of steam in quantities desired from minimum to maximum by simply turning the regulating valve.

(2) To prevent the warping or burning of the grate bars.



AMERICAN BANK NOTE CO., N.Y.

Wilkinson stoker under return-tubular boiler (longitudinal section).

As an example of the efficiency of this, I have only to say that the first stoker of this design was installed under a return tubular boiler in the Rebecca Paper Mill, at Bridgeport, Montgomery County, Pa., in December, 1891, and that the same identical grate bars are still in operation, apparently as good as when new, after six years' continuous use of twenty-four hours per day, equaling about twelve years' actual service of ten hours per day.

(3) The steam used in this device being pent up in an enclosed bar, and finding no other outlet but through an incandescent body of fire on the grate, becomes dissociated, and, uniting with the carbon of the fuel, produces a distribution of heat throughout the entire combustion chamber that cannot be produced in any other manner. Flame from anthracite coal to the extent of 40 feet is not an impossibility with this device, and with the use of bituminous coal of the lowest grade an entire and absolute smokeless result is obtained at all times.

The cost of producing these results in the use of steam is, as far as can be measured, from 5 per cent. to 7 per cent. of the steam generated in the boiler; that cost is, however, entirely wiped out by an increasing evaporation per pound of fuel burned.

Carefully conducted trials, in which the Wilkinson Company took no part whatever, show as high an evaporation as 12·9 pounds of water per pound of combustible, using anthracite buckwheat, which evidences as high an economy as hitherto known by any means.

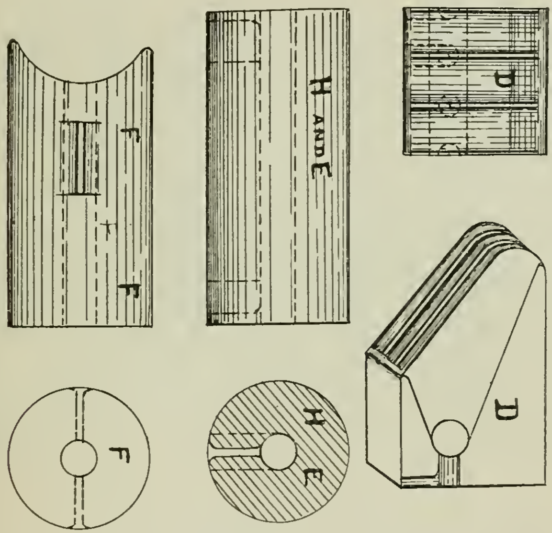
Capacity figures as an important factor also in this device. Mr. Jay M. Whitman, an expert engineer, of this city, reports to this company a test made by him in New York City of 126 per cent. over boiler rating, as the result of the performance of this stoker, with a satisfactory economy.

This stoker can be seen in operation in several of the most important industrial establishments in this city, whose addresses the Wilkinson Company will be pleased to furnish, and also at the works of the Wilkinson Company, at Bridgeport, Montgomery County, at any hour of the day, burning bituminous gas coal slack, *absolutely without smoke.*

THE McKENZIE SMOKELESS FURNACE.*

THE SECRETARY:—The McKenzie furnace is constructed on the well-known principle that air, properly admitted to the furnace and mixed with the gases, will give perfect combustion, preventing the formation of smoke, and at the same time giving the best efficiency from the fuel.

The secret of economy in the burning of fuel is perfect combustion. A smokeless furnace to be of practical use, must be adapted to all types of boilers; and it must have durability with simplicity of construction, which reduces the cost of repairs to a minimum.



SECT. PARTS McKENZIE FURNACE

The McKenzie furnace is designed to meet these requirements, as the following description of the furnace will show:

The furnace is made of heavy, refractory fire-brick material, especially burnt for us to withstand the strain of expansion and contraction caused by intense heat. We find the life of the material to be from two to five years, according to the work done. The side deflectors marked *D*, which are directly exposed to the flames, weigh 160 pounds each; the air columns marked *F*, weigh 375 pounds each; the cross distributors *H* and *E* also weigh 375 pounds each, making all the shapes exposed to the greatest heat substantial and durable. The deflectors *D* are built directly in the side walls of the furnace and overhang the grates, as shown in the cross-section, and are so designed that the back of the shape is heavier than the projecting nose, making it self-supporting in the wall, although the wall rests on it.

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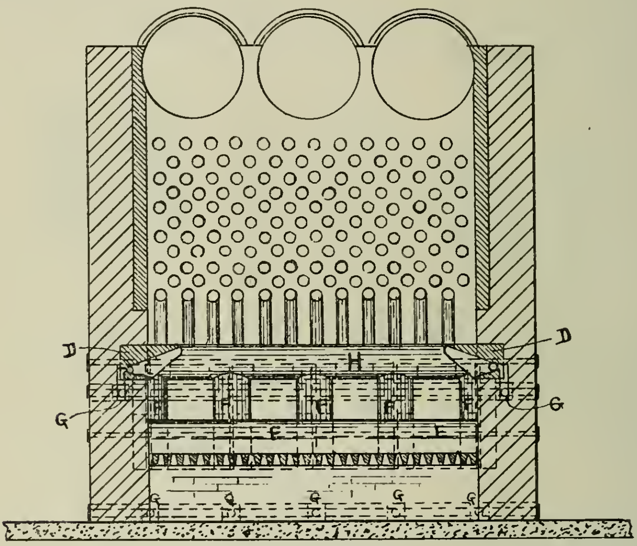
* Manufactured by the McKenzie Furnace Company, Chicago, Ill.



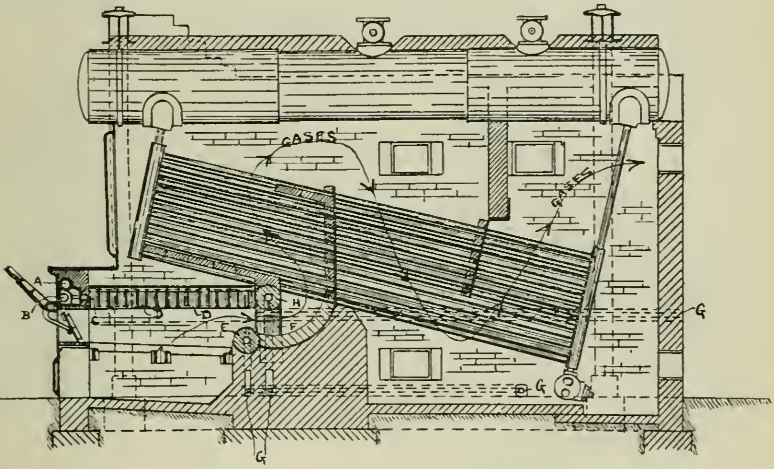
McKENZIE FURNACE
SECTION THRO FIRE BOX
WATER TUBE BOILER

The columns marked *F* are set in the bridge wall 18 inches apart, across the setting, and support the heavy cross distributor marked *H*, both being 14 inches in diameter and very strong. The other cross distributor marked *E*, is cemented on the top of the bridge wall near the end of the grate bars, as shown in the longitudinal section.

All the air distributors and vital parts are thoroughly protected from the firing tools.

The retort marked *A*, resting on the door liners, is made of cast-iron, protected from the fire by a fire-brick wall, the distributor marked *C*, is set in the retort 6 inches apart, and air, passing through the exposed lips, prevents them from fusing.

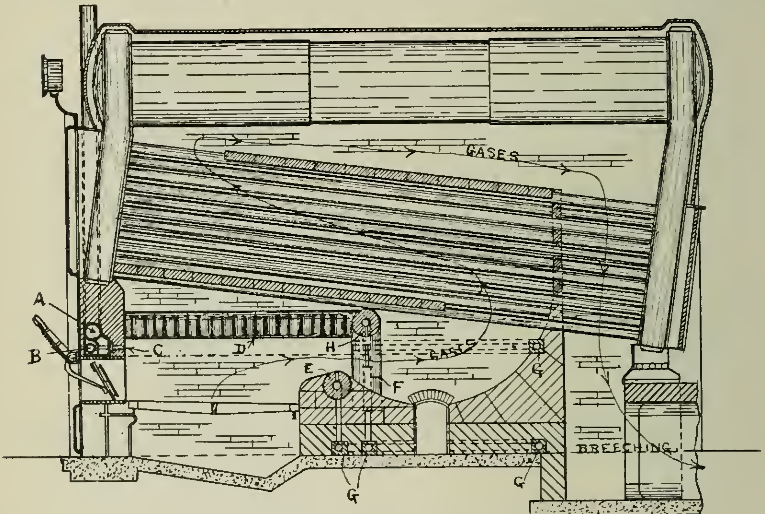
The door liners are made very heavy (1½ inches thick) to withstand the heat. The grates and fronts are the same in most cases as on ordinary furnaces; any grate can be used in connection with the furnace. The door is a lever-adjustable one, hanging on a hinge on either side of the liner and lifted by a finger in the center of door moved by the lever and ratchet, reducing the time of the door opening to a minimum, preventing the admission of cold air.



BABCOCK AND WILCOX BOILER
EQUIPPED WITH
McKENZIE FURNACE

The cost of repairing the furnace is very small, as the shapes are durable, can be reset by any handy man or mason about the plant, and are all interchangeable. In addition to this, it is never necessary to shut down the boiler to repair the furnace, as a damaged part will not materially affect its working, and can be repaired when it is convenient to shut down—a point very important where the boilers are pushed to their capacity and cannot be spared.

The operation of the furnace is the same as that of any hand-fired furnace; the air chambers requiring little or no attention, the opening at the side of the setting to the chambers marked *G*, being closed by a sliding iron door, which is opened to a fixed point regulated by the grade of coal used. On the cheapest grade of slack the doors are wide open, while with the best grade of coal the doors would be about one-third open. This point of opening is fixed by us, and regulated by the fuel used by the furnace, and, as the grade of coal used is generally the same from month to month, the air doors require no attention.



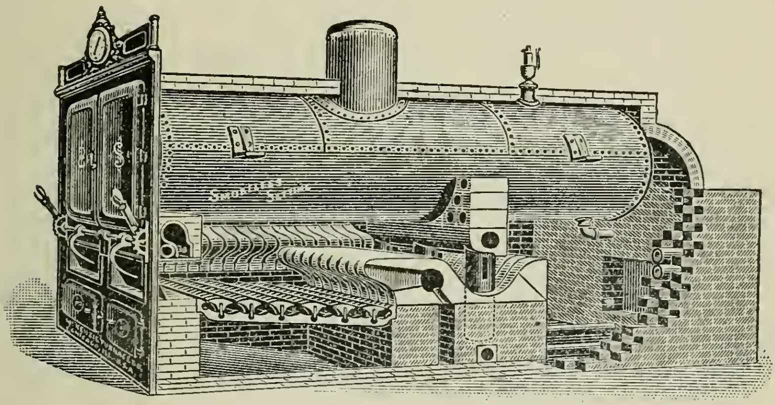
EDGEMOOR BOILER
EQUIPPED WITH
McKENZIE FURNACE.

As the furnace becomes heated, the air rushes in through the chamber, marked *G*, to the fire-box, through the long thin slots in the shapes, and is mixed with the gases at all points above the fuel, supplying sufficient oxygen for good combustion and preventing smoke. The retort, maked *A B C*, over the doors in front, also supplies air, and can be operated in two ways, either by admitting air at atmospheric pressure, or by admitting steam through the high-pressure retort, marked *B*, the steam passing through an opening $\frac{3}{64}$ inch in diameter through a nipple, forming a partial vacuum in the distributer, marked *C*, and forcing a larger quantity of air into the furnace.

In ordinary cases, the high-pressure retort is not used, and the air is admitted in much the same manner as through the other retorts.

The high-pressure retort is used only when it is necessary to force the boiler for capacity, and over 100 per cent. over-rating has been obtained on water-tube boilers when using this retort.

The steam taken by the high-pressure retort is less than 1 per cent. of the evaporation, and this is not considered a waste, as it pays for itself in the extra work done. All the air admitted goes into the furnace under atmospheric pressure, and is made to pass through the entire length of the setting in nearly all cases. This heats the air before it comes in contact with the gases and overcomes the bad effects of cold air.



McKenzie furnace attached to return tubular boiler.

We claim for the furnace the following meritorious points, all of which have been amply demonstrated in its practical service:

(1) The prevention of all objectionable smoke by the better combustion obtained. (2) Greater efficiency from the greater percentage of the calorific power obtained from the fuel. (3) More water evaporated per pound of coal from the better combustion. (4) Less coal consumption per horse-power per hour from better combustion. (5) Adaptability to

all types of boilers. (6) Moderate first cost, durability and ease of repairing. (7) Adaptability to plants where the quantity of steam used varies, and where there is necessity of getting steam very quickly, as in electric light plants; this is attained by the easier firing and the better and quicker combustion obtained. (From data furnished by the manufacturers.)

[*To be Continued.*]

ON THE THEORY OF LUBRICATION AND THE DETERMINATION OF THE THICKNESS OF THE FILM OF OIL IN JOURNAL BEARINGS.

By F. L. O. WADSWORTH, E.M., M.E.

In view of the practical importance of the subject of lubrication to mechanical engineers, it is surprising how little attention the theoretical consideration of the subject has received. The writer's interest in the subject was first aroused some years ago, while an undergraduate student at the Ohio State University. In 1886, Prof. Osborne Reynolds had published a paper in the *Transactions* of the Royal Society,* in which, for the first time, the subject was attacked from the ground of the theory of fluids, and some very important conclusions deduced and compared with the results of experiment. As these results do not seem to be as generally well known as their importance deserves, it may be well to first of all briefly review Professor Reynolds' paper. In doing so, I shall, in many cases, quote directly from the paper itself, because the author has stated his conclusions in so clear and concise a manner, that it would be impossible to condense or abbreviate his statements without losing some essential point.

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* "On the Theory of Lubrication and its Application to Mr. Beauchamp Tower's Experiments, including an Experimental Determination of the Viscosity of Olive Oil," by Professor Osborne Reynolds. *Transactions* Royal Society of London, Vol. 177, pp. 159-234, 1886.

The hydronamical equation for the flow of a viscous fluid, such as oil, in thin sheets, was simultaneously derived by Professor Reynolds and Lord Rayleigh and Professor Stokes.* It is

$$\frac{d\,p}{d\,x} = \frac{6\,\mu\,V\,(h - h_1)}{h^3} \tag{1}$$

where p is the intensity of pressure; V the velocity of motion of one side of the sheet with respect to the other, in the direction x; h, the distance between the shaft and the journal box (*i. e.*, the thickness of the oil film); h_1 being the value of h, for which p is a maximum; and μ the coefficient of viscosity. In the case of a journal revolving in its box, the equation is transformed as follows:

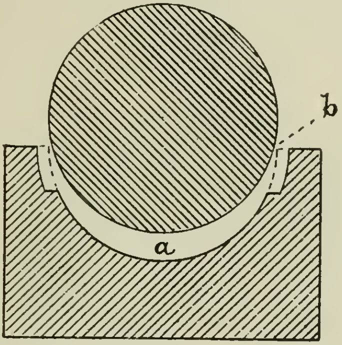

FIG. 1.

Let R (*Fig. 1*) be the radius of the shaft; $R + a$† that of the box. Let the center of the journal be at J, and that of the journal box at I, and let $J\,O$ be the line of load cutting the journal box symmetrically at L. Then if P denote any point x at the surface of the journal at which the pressure is p and the thickness of the film h; P_1 the point of greatest pressure, corresponding to the thickness h_1, and H the point of minimum thickness of the film; and if we put

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*See report of the meeting of the British Association for the Advancement of Science, Montreal, 1884.

† In the figure, a is greatly exaggerated to avoid confusion.

$$< OJP = \theta$$

$$< OJG = \frac{\pi}{2} - \phi_0$$

$$< OJP_1 = \phi_1$$

$$JI = ca$$

where c is a proper fraction,
we have directly (neglecting quantities of the order

$$\left(\frac{ca}{R}\right)^2$$

$$dx = R\,d\theta$$

$$h = a\,[1 + c\,sin\,(\theta - \phi_0)]$$

$$h_1 = a\,[1 + c\,sin\,(\phi_1 - \phi_0)]$$

and substituting these values in (1) we get

$$\frac{dp}{d\theta} = \frac{6\,R\,\mu\,V\,c\,[sin\,(\theta - \varphi_0) - sin\,(\varphi_1 - \varphi_0)]}{a^2\,[1 + c\,sin\,(\theta - \varphi_0)]^3} \qquad (2)$$

In the case of a journal freely revolving in its box and separated from it by a film of oil of thickness h, there is a condition of equilibrium when the resultant of the pressure p, plus the frictional resistance to motion, f, is equal to the external load L and opposed to it in direction; *i. e.*, acts along the line $J\,O$. When there is no longitudinal pressure in the bearing the only remaining unbalanced force is one tending to rotate the journal box. Let M denote the moment of this force per unit length of the shaft. Then we have the additional equations:

For resultant of forces along $O\,J$

$$= L = \int_{-\theta_1}^{+\theta_1} (p\,cos\,\theta + f\,sin\,\theta)\,R\,d\theta \qquad (3)$$

For resultant of forces at right angles to $O\,J$

$$= O = \int_{-\theta_1}^{+\theta_1} (p\,sin\,\theta - f\,cos\,\theta)\,R\,d\theta \qquad (4)$$

For turning moment on box

$$= M = R \int_{-\theta_1}^{+\theta_1} f\,R\,d\theta \qquad (5)$$

$2\theta_1$ being the extreme angle $C\ I\ D$ (bisected by the line $J\ O$), subtended by the journal box.

At the edges of the box the pressure $p = p_0$, the external pressure of the film, usually simply that of the atmosphere.

For the frictional resistance between two parallel plane surfaces moving with a relative velocity, V, and separated by a film of viscous fluid of thickness, a, we have

$$f = \mu \frac{V^*}{a} \tag{6}$$

In the case of a cylindrical bearing and a film of variable thickness h, this expression becomes

$$f = \frac{3\,\mu\,V\,c\,[\sin(\theta - \varphi_0) - \sin(\phi_1 - \phi_0)]}{a\,[1 + c \sin(\theta - \phi_0)]^2} - \frac{\mu\,V}{1 + c \sin(\theta - \phi_0)} \tag{7}$$

$$K_1 = \frac{6\,R\,\mu\,V}{a^2}$$

These equations can be integrated directly for very small values of c, and were integrated by methods of approximation (of which it is unnecessary to give details here) for various values of c, up to $c = 0{:}5$, beyond which point the particular methods of approximation adopted can no longer be applied.

From these results Professor Reynolds has computed the following table, giving the pressure round the bearing at intervals of 10°, and also at particular points, $\theta = \pm 29° 20' 20''$, two points at which the pressure was experimentally measured in certain experiments of Mr. Tower, with which the results of theory are subsequently compared; $\theta = \pm 78° 31' 20''$, the extreme edges of the boxes; $\theta = -7° 21' 40''$, the point of maximum pressure P_1; and $\theta = -76° 38' 20''$, the point of minimum pressure.

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[*] This supposes that there is no slipping at the boundary between the fluid and the surfaces in contact with it. That there is no such slipping (at least when the film is thin) has been established by the experiments of Poiseuilles (Paris : Mem. Savants Etraug., Tome 9, p. 434, 1846), and of Reynolds (Phil. Trans., Vol. 174, p. 935, 1883).

θ (on side)*	$\frac{p - p_0}{K_1 c}$	θ (off side)*	$\frac{p - p_0}{K_1 c}$
78° 31′ 20″	·0002	0° 0′ 0″	1·0151
70°	·1002	—7° 21′ 40″	1 0269
60°	·2249	—10°	1·0232
50°	·3555	—20°	·9412
40°	·5003	—29° 20′ 20″	·7923
29° 20′ 20″	·6609	—40°	·5612
20°	·8022	—50°	·3349
10°	·9331	—60°	·1449
0°	1·0151	—70°	·0293
		—76° 38′ 20″	—·001
		—78° 31′ 20″	·0002

$$K_1 \frac{6 R \mu V}{a^2}$$

Since the value of $p - p_0$ varies directly as R and V and inversely as a^2, it follows that since the latter quantity is very small, while the two former may be very large, the pressure in the film of oil may sometimes rise to a very high figure. In one case, indeed, the difference, $p - p_0$, was found by actual measurement to be over 600 pounds per square inch. And it is the very fact of this excess of pressure in the film, produced and maintained by the motion of the journal, that explains its existence. The theory also definitely indicates the greatest load which the journal will carry at a given speed without rupturing this oil film. "As the ratio of the load to velocity increases, $J\ I$ or c increases, and the point H approaches G, when c reaches the value 0·5, which makes $G\ H = a\ (1 - c) = 0{\cdot}5\ a$, the pressure of the oil in the film is everywhere greater than at A and B, the pressure in the bath, but for a further increase in the load the pressure falls near A on the *off* side, the fall will cause the pressure to become less than that of the atmosphere, or if sufficient, to become absolutely negative, until discontinuity or rupture of the film occurs. The film will then only extend between brass and journal over a portion of the whole arc, and a smaller portion as the load increases or velocity diminishes, *i. e.*, as c increases. Thus, since the amount of negative pressure which the oil will bear depends on circumstances which are uncertain, the limit of the safe load for complete lubrication is that which causes the least separating distance to be half the difference in radii of the brass and journal.

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* "On" and "off" are used by Professor Reynolds to denote respectively the sides of approach B and of recession A in *Fig.* 1, the arrow indicating the direction of motion. In the paper, the angles θ are reckoned from $J\ O$ each way; + to right; — to left.

"The rupture of the oil does not take place at the point of nearest approach, but on the *off* side of this, and will only extend up to a point P_2 definitely shown in this theory, which is at the same distance on the *off* side of H as P_1 is on the *on* side. Hence, after this rupture, the brass may still be in equilibrium, entirely separated from the journal, and the question as to whether it will carry a greater load without descending on to the journal will depend on the relative values of

$$\frac{a}{R}$$

and on the smallness of the velocity."

* * * * * * * * *

"This much may be inferred without effecting the integrations for imperfect lubrications; could these be effected, the theory would be as applicable to partial lubrication as it has been to complete lubrication, *i. e.*, a sufficient supply of oil. And as it is, sufficient may be seen to show that with any supply of oil, however insufficient for complete lubrication, the brass will still be completely separated from the journal, although the supporting film of oil will not touch the brass except over a limited area."

* * * * * * * * *

"Another circumstance brought out by this theory, and remarked on both by Lord Rayleigh and the author at Montreal, but not before suspected, is that the point of nearest approach of the journal to the brass is not by any means in the line of load, and what is still more contrary to common supposition, it is on the *off* side of this line.

"This point H moves as the ratio of load to velocity increases; when this ratio is zero, the point H coincides with O, then as the load increases, it moves away to the left, till it reaches a maximum distance,

$$\frac{\pi}{2} - \varphi_0,$$

being nearly

$$-\frac{\pi}{2}$$

The load is still small. * * * For further increase of load, H returns towards O, or

$$\frac{\pi}{2} - \varphi_0$$

increases with the largest loads and smallest velocities to which the theory has been applied; this angle is about 40°. With a fairly loaded journal well lubricated, it would thus seem that the point of nearest approach of brass to journal, *i. e.*, the center of wear, would be about the middle of the *off* side of the brass.

"This circumstance, the reason of which is rendered perfectly clear by the conditions of equilibrium, at once explains a singular phenomenon, * * * viz.: that the journal having been run in one direction for some time, and carrying its load without heating, on being reversed, began to heat again, and this after many repetitions always heating on reversal, although eventually this tendency nearly disappeared.

" * * * This is an effect which would necessarily follow in accordance with the theory, so long as there is wear. For the center of wear, being on the *off* side of the line of loads, this wear will tend to preserve or diminish the radius of the brass on the *off* side, and enlarge it on the *on* side, a change which will, if anything, improve the condition for producing oil pressure while running in this direction, but which will damage the condition on which the production of pressure in the film depends when the journal is reversed and the late *off* side becomes the new *on* side. That with a well-worn surface there should be sufficient wear to produce this result, with * * * slight amounts of using * . * * before reversal, seems doubtful; but supposing the brass new, and the surface more or less unequal, the wear for some time would be considerable, even after the initial tendency to heat had disappeared. Hence it is not surprising that the effect should have eventually seemed to disappear."

As regards the frictional resistance of a revolving shaft, the equations (6) and (7) show that it should be directly proportional to the velocity and to the viscosity of the oil, and inversely proportional to the difference of radii of the shaft and bearing. If these two last quantities are constant, the friction will increase directly as the speed, and will be independent of the load. In general, this will not be the case, because both μ and a are themselves functions of both the velocity and the load. Before comparing the results of theory with practice, it is therefore necessary to consider the causes that may cause variations in the values of μ and a. Of these variations, the most important are (1) those due to temperature changes; (2) those due to the pressure in the oil film.

(1) Change in temperature affects—

(*a*) The viscosity of the oil. By a series of experiments on olive oil Reynolds found that between temperatures of 16° and 49° C. the variation in viscosity could be expressed by an exponential law of the form

$$\mu_x = A_0 e - C(t_x - t_0) \qquad (8)$$

where

A_0 = viscosity at temperature t_0 * * * $t_0 = O$

C = coefficient of change for 1° C. * * *

for olive oil

$t_0 = O.$

$A_0 = 3{:}265$ C. G. S. units.

$C = 0{\cdot}0123.$

(*b*) The value of a by reason of difference in coefficient of expansion of the metal of the journal and journal box.

This variation may be expressed in the form

$$a_x = a_0 [1 + E (t_x - t_0)] \tag{9}$$

E being the rate at which a increases with temperature. Since E is small (in case of a brass journal box and steel journal 4 inches in diameter, E is about 0·00004), we may put (9) in a form similar to (8), or

$$a_x = a_0 \, e^{E (t_x - t_0)}$$

(2) Change in pressure affects also the value of a by reason of the elasticity of the material of the journal box. If we take m as the coefficient of this effect, the variation of a with the load, L, may be expressed

$$a_x = a_0 + m \, L \tag{10}$$

The total effect on a, due both to rise of temperature $t_x - t_0$ and to load L, will therefore be

$$(a_0 + m \, l) \, e^{E (t_x - t_0)}$$

The friction at temperature t_x and load L will be from (6)

$$f = \frac{\mu_0}{a_0 + m \, L} \, V e^{-(C+E)(t_x - t_0)} \tag{11}$$

In any series of experiments, V, the velocity; L, the load; f, the friction actually overcome; and t_0, the temperature of the journal box and shaft, may be measured, and the values of C and μ determined from independent experiments, as already noted. But a_0, m, and particularly t_x, the actual temperature of the oil film, are unknown. Since the oil film is itself the seat of the heating, it is only reasonable to suppose that it will be at least several degrees higher in temperature than the surrounding metal. This rise in temperature is caused by the work spent in overcoming friction, and the heat thus generated has all to be carried away by the oil film (by bodily movement of the oil) or conducted away through the metal surfaces in contact with it. "Consideration of this work and the means of escape gave another equation between the rise of temperature, the friction and the velocity," viz.:

$$f = \left(A + \frac{B}{V}\right)(t_x - t_0) + E\,A\,(t_x - t_0)^2 \qquad (12)$$

where $A + E\ (t_x - t_0)$ represents the rate at which the mechanical equivalent of heat is *carried* away (by the oil) per 1° rise in temperature, B represents the rate at which it is conducted away (by boxes, shaft, etc.).

Comparison of Theory with Experiment.—Professor Reynolds has compared the results of theory with the results of a long series of careful experiments by Mr. Tower, which were undertaken at the instance of the English Institute of Mechanical Engineers.* Although the friction of lubricated surfaces has been the subject of a great deal of experimental investigation by able and careful experimenters, and, "in many cases empirical laws have been propounded; these fail for the most part to agree with each other and with the more general experience." The main cause of this irregularity was found by Mr. Tower to be irregularity in the supply of lubricant. In order to remove this cause as far as possible, he, in one series of experiments, completely immersed the journal box in an oil bath, which was maintained at a definite temperature. "This was very fortunate, for * * * the results so obtained show a great degree of regularity. They show that with perfect lubrication a definite law of the variation of the friction with the pressure and the velocity holds for a particular journal and brass." When Mr. Tower substituted for the bath an oil-pad pressed against the free part of the revolving journal, he also found considerable regularity in the results, but these results were very different from those obtained with the bath. With intermediate lubrication he obtained intermediate results, of which he says: "Indeed, the results, generally speaking, were so uncertain and irregular, that they may be summed up in a few words. The friction depends on the quantity and uniform distribution of the oil, and may be anything between the oil-bath results and seizing, according to the perfection or imperfection of the lubrication."

Of Mr. Tower's experiments, therefore, only those made with the oil-bath can be compared with the results of the theory developed by Professor Reynolds, which has been fully developed, as already pointed out, only for the case of perfect lubrication, *i. e.*, continuous supply of oil at the *on* side of the journal box. In Mr. Tower's experiments, the values of f were measured for various values of V and L, with two boxes, which are designated, respectively, as Nos. 1 and 2. The temperature t_0 measured was that of the oil-bath. The first step in the comparison of the theoretical with the experimental results was to determine t_x, the actual temperature of the oil film. This was done by substituting in equations (11) and (12) the experimental values of f, V, L and t_0, and then determining from these observation equations the value of t_x and of the constants, A, B, E, m and a_0. The test of the theory is in these values being constant throughout the range of experiment.

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* Proc. Inst. Mech. Engineers (English), 1883, 1884.

"It was * * * found that the experiments with the lower loads gave remarkably consistent values for A, B, E, m and a_0, which was also treated as arbitrary. In proceeding to the higher loads for which values of c were greater, the agreement between the calculated and experimental results was not so close, and the divergence increased as c increased. On careful examination, however, it appeared that this discordance would be removed if the experimental frictions were all reduced 20 per cent. This implied that 20 per cent. of the actual friction arose from sources which did not affect the pressure of the film of oil; such a source would be the friction of the ends of the brass against flanges on the shaft, commonly used to keep the brass in its place, or by any irregularity in the longitudinal section of the journal or brass. Although no direct reference is made to such flanges in Mr. Tower's reports, it is such a common custom to neck the shaft to form the journal, that there is great probability of the flanges being used. A coefficient, n, has, therefore, been introduced into the theory, which includes both the effect of necking and of irregularity in longitudinal section. Giving n the value 1.25, the calculated results came into accordance with all Mr. Tower's results for olive oil, the difference being such as might well be attributed to experimental inaccuracy, and this both as regards the frictions measured with one brass, No. 1, and the distribution of the pressure round the journal with another, No. 2."

"Not only does the theory thus afford an explanation of the very novel phenomena of the pressure in the oil film, but it also shows, what does not appear in the experiments, how the various circumstances under which the experiments have been made affect the results."

"Two circumstances in particular, which are brought out as principal circumstances by the theory, seem to have hitherto entirely escaped notice, even that of Mr. Tower."

"One of these is a, the difference in the radii of the journal and of the brass or bearing. It is well known that the fitting between the journal and its bearing produces a great effect on the carrying power of the journal, but this fitting is supposed to be rather a matter of smoothness of surface than a degree of difference in radii. The radius of the bearing must always be as much larger than that of the journal as is necessary to secure an easy fit, but more than this does not seem to have been suggested."

"It now appears from this theory that if viscosity were constant, the friction would be inversely proportional to the difference in the radii of the bearing and journal, and this, although the arc of contact is less than the semi-circumference; and taking temperature into account, it appears from the comparison of the theoretical frictions with the experiment on brass No. 1, that the difference in the radii at 70° F. was

$$a = 0{\cdot}00077 \text{ (inch)}$$

and comparing the theoretical pressures with those measured with brass No. 2,

$$a = 0{\cdot}00084 \text{ (inch)}$$

or the difference was 9 per cent. greater in the case of brass No. 2."

"These two brasses were probably both bedded to the journal in the same way, and had neither been subjected to any great amount of wear, so that there is nothing surprising in their being so nearly the same fit. It would be extremely interesting to find how far, under continuous running, prolonged wear tends to preserve this fit. Mr. Tower's experiments afford only slight indication of this. It does appear, however, that the brass expanded with an increase of temperature, and that its radius increases as the load increases in a very definite manner."

The general results of the comparison are finally summed up as follows:

"The experiments to which the theory has been definitely applied may be taken to include all Mr. Tower's experiments with the 4-inch journal and oil-bath, in which the number of revolutions per minute was between 100 and 450, and the nominal loads in pounds per square inch between 100 and 415. The other experiments with the oil-bath were with loads from 415 till the journal seized at 520, 573 or 625, and a set of experiments with brass No. 2, at twenty revolutions per minute. All these experiments were under extreme conditions, for which by the theory c was so great as to render lubrication incomplete, and preclude the application of the theory without further integrations.

"The theory has, therefore, been tested by experiments throughout the extreme range of circumstances to which the particular integrations undertaken are applicable, and the results, which in many cases check one another, are consistent throughout.

"The agreement of the experimental results with the particular equations obtained on the assumption that the brass as well as the journal are truly circular, must be attributed to the same causes as the great regularity presented by the experimental results themselves.

"Fundamental amongst these causes is, as Mr. Tower has pointed out, the perfect supply of lubricant obtained with the oil-bath. But nearly as important must have been the truth with which the brasses were first fitted to the journal, the smallness of the subsequent wear and the variety of the conditions as to magnitude of load, speed and direction of motion.

"That a brass in continuous use should preserve a circular section with a constant radius requires either that there should be no wear at all, or that the wear at any point P should be proportional to

$$sin\left(\frac{\pi}{2} - P\,J\,H\right)$$

"Experience shows that there is wear in ordinary practice, and even in Mr. Tower's experiments there seems to have been some wear. In these experiments, however, there is every reason to suppose that the wear would have been approximately proportional to

$$c\ sin\,(\varphi_0 - \theta) = c\ \ sin\left(\frac{\pi}{2} - P\,J\,H\right)$$

because this represents the approach of the brass to the journal within the mean distance a, for all points, except those at which it is negative; at these there would be either no wear at all, or a slight positive wear. So long, then, as the journal ran in one direction only, the wear would tend to preserve the radius and true circular form of that portion of the arc from A to F,* altering the radius at F, and enlarging it from F to B. On reversal, however, A and F change sides, and hence alternate motion in both directions would preserve the radius constant all over the brass.

"The experience emphasized by Mr. Tower, that the journal, after running for some time in one direction, would not run at first in the other, strongly bears out this conclusion. Hence it follows that had the journal been continuously run in one direction, the condition of lubrication, as shown by the distribution of oil pressure round the journal, would have been modified, the pressure falling between O and B on the *on* side of the journal, a conclusion which is borne out by the fact that in the experiments with brass No. 2, which was run for some time continuously in one direction, the pressure measured on the *on* side is somewhat below that calculated on the assumption of circular form, although the agreement is close for the other four points.

"When the surfaces are completely separated by oil, it is difficult to see what can cause wear. But there is generally metallic contact at starting, and hence abrasions, which will introduce metallic particles into the oil (blacken it); these particles will be more or less carried round and round with the journal, causing wear and increasing the number of metallic particles and the viscosity of the oil. Thus the rate of wear would depend on the metallic particles in the oil, the values of,

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* A point 90° from G in the direction $G\ O\ B$.

$$c, \frac{1}{a}$$

and the velocity of the journal, and hence would render the greatest velocity of the journal at which the maximum load with a large value of c could be carried, small—a conclusion which seems to be confirmed by Mr. Tower's experiments with brass No. 2, at twenty revolutions a minute.

"In cases such as engine bearings, the wear causes the radius of curvature of the brass continually to increase, and hence, a and c must continually increase with wear. But, in order to apply the theory to such cases, the change in the direction of the load (or the velocity of approach of the surfaces) would have to be taken into account.

"That the circumstances of Mr. Tower's experiments are not those of ordinary practice, and hence that the particular equations deduced in order to apply the theory definitely to these experiments do not apply to ordinary cases, does not show that the general theory, as given in the general equation, could not be applied to ordinary cases were the conditions sufficiently known.

"These experiments of Mr. Tower have afforded the means of verifying the theory for a particular case, and hence have so far established its truth as applicable to all cases for which the integrations can be effected.

* * * * * * * * *

"The verification of the equations for viscuous fluids under such extreme circumstances affords a severe test of the truth and completeness of the assumptions on which these equations are founded; and the result of the whole research is to point to a conclusion that not only in cases of intentional lubrication, but whatever hard surfaces under pressure slide over each other without abrasion, they are separated by a film of some foreign matter, whether perceptible or not; and that the question as to whether the action can be continuous or not, turns on whether the motion tends to preserve the foreign matter between the surfaces at the points of pressure, as in the almost if not quite unique case of the revolving journal, or tends to remove it, and sweep it on one side, as is the action of all backward and forward rubbing with continuous pressure.

"The fact that a little grease will enable any surfaces to slide for a time has tended doubtless to obscure the action of the revolving journal to maintain the oil between the surfaces at the point of pressure, and yet, although only now understood, it is this action that has alone rendered machinery or even carriages possible. The only other self-acting system of lubrication is that of reciprocating motion with intermittent pressure and separation of the surfaces to draw the oil back or to draw a fresh supply. This is important in certain machinery, as in the steam engine, and is as fundamental to animal mechanism as is the continuous lubricating action of the journal to mechanical contrivances."

* * * * * * * * *

Measurement of the Thickness of the Oil Film in a Journal Bearing.—Although the remarkable agreement between Professor Reynolds' theory and the results of Mr. Tower's experiments seems to demonstrate conclusively the correctness of the former (as well as the accuracy with which the latter were made), it was thought that it might be interesting to confirm Professor Reynolds' conclusions in an entirely independent manner, *i. e.*, by directly measuring a, the difference in radii between journal box and shaft, under different conditions of load, velocity and temperature. Professor Reynolds considers that there is no method by which this can be directly accomplished; but it occurred to the writer that it might be indirectly done with considerable accuracy by measuring h, the mean thickness of the oil film. In 1888, I spent considerable time in devising plans by which the problem might be experimentally attacked under actual working conditions. Of the methods which suggested themselves at the time, that which seemed the most promising and practical was to measure the electrical resistance between the box and the shaft when the latter was in motion and at rest. In the latter case the shaft is practically in metallic contact with its box, and the resistance is very low; but in the latter, when it is separated from it by a thin film of oil, the resistance will be raised by an amount depending on the thickness of the film. In order to determine from the measured resistance the thickness of the film, it is necessary to know the specific resistance of the oil and its temperature coefficient, and the temperature and area of the oil film.

It is further necessary to know whether the thickness of the film is uniform, or, if not, in what way it varies.

As regards the general temperature of the oil, t_0, this is easily determined by means of a thermometer placed in a deep cavity in the metal of the box or shaft, as near the bearing surface as possible, the cavity being filled with water, or preferably mercury; or directly in the oil-bath surrounding the shaft, as in Tower's experiments. The mass of the metal surrounding the bearing surfaces is so great in comparison with the mass of the oil, and its conductivity is so high, that the temperature recorded by this thermometer could be but very little lower than the temperature of the oil film itself, which is the seat of the heating. This last can also be directly determined in the manner indicated by Reynolds, from measurements of the friction, f. The area of the film is, of course, the total area of the bearing between box and shaft. The point most difficult to deal with is that of the variation in the thickness of the film over the bearing surfaces. Two distinct causes, which may be classed, respectively, as irregular and regular, tend to introduce differences in thickness between different parts of the oil film. The first includes such irregularities as are due to roughness or inequalities in the surfaces of the box or shaft, or to the introduction of particles of metal by abrasion, etc. The first cause of irregularity may be avoided by choosing for the experiments a shaft and journal box which have first been carefully fitted to each other, and then allowed to run together (first in one direction, then in the other), a sufficient length of time under light pressure to produce perfectly smooth and polished surfaces; the second by carefully cleaning the box and shaft with benzine before beginning the experiments, and then during the measurements keeping the bearing continually supplied with clean, fresh oil, from a suitable reservoir.

The regular causes of variation in thickness are, first, the differences in pressure in different parts of the journal box. The effect due to differences in pressure can be very nearly eliminated for the purposes of experiment by using two boxes and applying a pressure to the top box, which is equal to the pressure exerted on the box by the weight of the shaft and attached mechanism, or by using, as was done in this case in the experiments which were begun, a Thurston oil-testing machine,* in which the journal brasses are brought together by a spring which acts simultaneously and equally on both top and bottom brasses. A further advantage of using this machine is that the work lost in friction and therefore the heat developed in the box in any given length of time may be conveniently and accurately measured in each experiment. The second cause of variation is that due to eccentricity of the shaft in the box, produced by the variation in the thickness of the film itself. If the bearings are perfectly fitted to each other when they are actually in contact (see *Fig. 2*), then when the two are separated slightly, the opening between the two is greater at the bottom, *a*, than at the edges *b*. In practice, however, the two are more likely to be concentric when slightly separated than when actually together, because that is the condition under which wear between the two takes place. (See Reynolds' remarks, already quoted). Hence, if, as is nearly always the case, the box is softer than the shaft and the two are allowed to run together any length of time at a given pressure equally applied to both boxes, the surfaces will at that pressure be nearly if not quite concentric, particularly if the sides of the box are slightly relieved, as shown in dotted lines in *Fig. 2*, and the direction of motion is frequently reversed.

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* For description see Professor Thurston's "Friction and Lost Work in Machinery and Mill Work," John Wiley and Sons, New York; also Pratt & Whitney's Catalogue, 1893 ed., pp. 289-91.

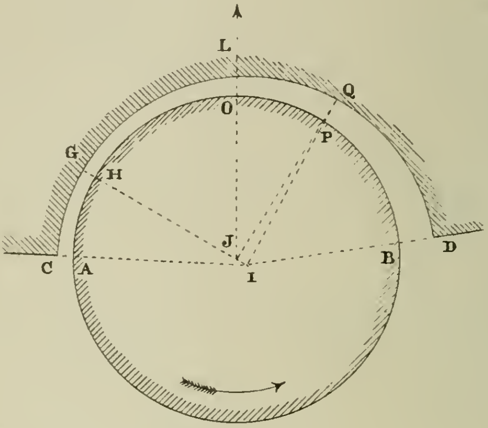

FIG. 2.

In order to carry out this method of measuring the thickness of the oil film, it was first necessary to determine the specific resistance and temperature coefficient of the oil used in the experiments. This was done by the method and with the results recorded in the supplement to this paper. The second part of the investigation, the measurement of the resistance of the film of oil in the journal bearing, had just been begun when the work was interrupted by my departure from the University to accept a Fellowship at Clark University. Since then, I have always hoped to be able to carry the work to completion, but the continued pressure of other duties, as well as the want of appropriate apparatus, has so far prevented me from taking it up again. As I am now permanently engaged upon other entirely different lines of investigation, I have decided to publish the account of the work already completed, in the hope that the results so far obtained may not be uninteresting in themselves, and that some one who has a good oil-testing machine (like the Thurston) and the other necessary apparatus (a low resistance galvanometer, box of coils, etc.,) at his disposal, may be sufficiently interested in the problem to continue the work along the lines indicated in this paper.

Although the work was interrupted before the complete apparatus for the resistance measurements had been set up and put in working order, some interesting preliminary results had been secured by placing an ordinary (comparatively insensitive) tangent galvanometer directly in series with a resistance box and the revolving shaft, a single gravity cell being used to furnish the current. Qualitative results were thus secured, showing that the resistance was measurably increased even when the pressure was very great and the speed very slow.* The deflection of the galvanometer decreased very rapidly (showing rapid increase of resistance) when the speed was raised or the pressure diminished. Under any one condition the deflection was as constant as could have been expected considering the conditions of the experiment, there being at the time no provisions for a constant supply of oil or for the maintenance of constant speed. The method, therefore, seems a promising one.

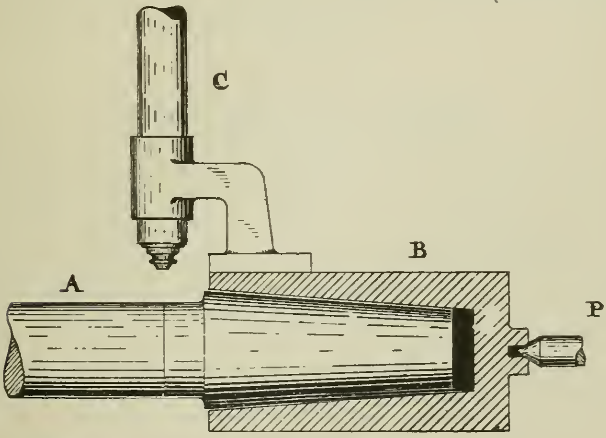

FIG. 3.

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* This at least confirms Reynolds' conclusion that a film of oil is always present between the moving surfaces.

ADDENDUM.

While writing these notes, another plan of measurement has occurred to me which would be useful as a check on results obtained by the electrical method, although it has not the advantage of the latter in allowing results to be obtained under the same conditions as usually obtain in machine bearings. This would be to have a long conical bearing, *Fig. 3*, accurately fitted to a solid box *B*, whose longitudinal position with respect to the revolving shaft *A* can be accurately located by means of a microscope *C*, mounted on the box and focussed on a fine circumferential line on the shaft. The thickness of the oil film in this case is determined by the longitudinal motion of *B* on *A*. Differing pressures between shaft and box may be produced by a spring or weighted lever acting on the end of the box at *P*.

YERKES' OBSERVATORY, MARCH, 1897.

[*To be concluded.*]

NOTES AND COMMENTS.*

PROPOSED SHIP CANAL FROM THE BALTIC TO THE BLACK SEA.

The Russian government is said to be seriously contemplating the construction of a great ship canal between the Baltic and Black Seas, entirely through Russian territory, to connect the northern and southern portions of the empire. The military value of such a canal in permitting of a concentration of all the available naval force of the empire at one or the other of these points would unquestionably prove of the highest importance ; but, in addition to this obvious advantage, it is believed that its value to the agricultural and industrial interests of Russia would be scarcely less important.

We reproduce from the New York *Sun* the following data bearing on the subject :

After a thorough study of the various possible roads, one has been selected as the most practical, running, as it does, entirely through Russian territory. On the plan selected there are no great difficulties of level to be overcome, although the European watershed summit has to be crossed, but this last takes place at one of its lowest points.

The proposed canal's entrance will be on the Gulf of Riga, at the mouth of the River Duna. It will follow the course of this river up to a point above Dunabourg. Then, leaving this valley, it reaches the Berezina River by a straight cut and passes through Babrouisk. This brings it into the Dnieper, and following this natural declivity it reaches the Black Sea, opening into a magnificent roadstead below the Kerson. The total length of this colossal waterway will be something like 1,600 kilometers (about 1,000 miles), and it will be excavated to a depth of 8½ meters (about 27 feet). This will allow the largest iron-clads to navigate it freely from one end to the other. The estimated cost is put down at $500,000,000.

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*From the Secretary's monthly reports.

Its strategic importance does not need demonstration. By the selection of a course running at a safe distance from the frontier, it places back of the Russian forces stationed in Poland an unassailable base of operation. Fully protected already by a whole network of fortifications and railways, this canal is intended to act as a feeder for all the war material. As to the concentration of the whole Russian fleet in the Black Sea, this means an absolute control of Constantinople and the Straits.

But if this enterprise is of the utmost importance in a military point of view, it will also prove unquestionably very beneficial to the agricultural and industrial interests of the country. It places vast grain-producing regions in cheap communication with Odessa, the chief point of export, while the immense coal fields of Southern Russia will come into easier connection with the industrial districts of Poland. There are reasons, too, to believe that new factories will develop along the canal on account of the cheapness of this new mode of transport. If this scheme has been adopted, there is no doubt that the Russian tenacity will bring it to success.

TELEGRAPHY WITHOUT WIRES.

The following intelligent summary of the present status of the problem of telegraphy is condensed from a recent editorial utterance of the *Scientific American*, and will be found of interest:

Nikola Tesla has lately announced that he has completed his wireless telegraph to such an extent as to permit of telegraphy through the earth for a distance of twenty miles or more, and his experiments satisfy him of the feasibility of wireless telegraphy on a much more extended scale. In fact, he aims at nothing less than the establishment of a system of telegraphy that shall include the whole earth, and by which items of news may be distributed from one political or commercial center to every other such center throughout the world. This, Mr. Tesla claims, is possible without the interference of one set of signals with another.

He has constructed and tested both transmitting and receiving apparatus, and has found that a surprisingly small expenditure of energy is required. It is impossible, at this writing, to secure details of the apparatus, but it is known that he utilizes the static equilibrium of the earth. This he disturbs at one point, making signals which can be distinguished at one or more distant points.

In his earlier experiments in high frequency currents Mr. Tesla attained a frequency of 10,000 per second; now 2,000,000 oscillations per second is not deemed extraordinary. It is said that the success of the system is assured, but he will not come before the public until every detail is completed. It is understood that the transmission of power from place to place by means of a similar system is contemplated.

While Mr. Tesla has been wrestling with this great problem in this country, Mr. Marconi, a young Anglo-Italian, has been working on the same line in England under the direction of Mr. Preece. It is reported that Mr. Preece has succeeded in telegraphing with certainty and sufficient rapidity from Penarth to Weston-super-Mare, a distance across the water of seven or eight miles, without wires, and it is believed that this distance can be greatly extended.

It is said by *The Engineer* that the apparatus devised by Marconi is extremely ingenious, and has for its object the getting out of the Hertzian vibrations sufficient work for telegraphic purposes. The apparatus comprises a transmitter and receiver. The former consists mainly of a small Ruhmkorff induction coil excited by a couple of battery cells. The secondary or high tension wires terminate each in a metallic ball. Between the two balls is placed a cubical box containing oil. In the opposite sides of the box are fixed two brass balls, oil-tight, so that one-half of each ball is in the oil in the box and the other half outside of the box. The balls do not touch. The whole arrangement has been designed by an Italian professor, Righi. On sending a a current through the induction coil, Hertzian vibrations are set up in the balls and communicated to the ether. The oil has a peculiar effect, acting as a species of brake, the rapidity of the wave vibrations being only about one-half of that stated by Dr. Lodge. These vibrations are then given off into space all around in every direction. So far as known, nothing save metals appears to be opaque to them, and here, therefore, we have an analogy with the Röentgen ray.

Marconi's receiver consists of a tube about ¼ inch in diameter and 3 inches long, in which are two silver plugs terminating in wires, the ends of which are soldered to the silver plugs. The wires are fused into the glass. The tube is exhausted to a near approach to absolute vacuum. The faces of the two silver plugs are very close to each other, and the space between is filled up with an impalpable metallic dust. On the nature of this dust much depends. It must suffice to say that there are in it three constituents, one of which is nickel. Under ordinary conditions this powder will not conduct electricity, save feebly. Its resistance is very high. If a Hertzian ray falls on the little tube, the dust is polarized like the filings in a Hughes test tube, and the powder becomes a conductor. It will be seen at once that we have here a make and break which can be acted on from a distance, and an ordinary Morse sounder does the rest. But matters, after all, are not quite so simple. It is easy to dispatch into space Hertzian waves at intervals corresponding to dots and dashes, but the powder in the receiver, once polarized, remains polarized. To get over this obstacle, a tiny hammer is so arranged that, the moment a current passes through the tube, the hammer taps the side of the tube and depolarizes the powder ready for the next signal.

There is nothing in common between ethereal or wireless telegraphy and telegraphy by induction ; the phenomena are wholly distinct. The Hertzian radiance is akin to light, and the polarization of the powder in the receiver finds its analogue in the molecular change which is wrought by light in a sensitized plate.

THE EXPORTATION OF AMERICAN TIN PLATES.

The *Iron Age* is our authority for the interesting statement that the American Tin Plate Company, of Elwood, Ind., has begun the shipment of tin plate to Europe, on regular orders, the first carload of 500 boxes (first quality) having been shipped on an Italian order, on August 11th. A similar order, we are informed by the same authority, is being filled for England.

The *Iron Age* makes some suggestive comments on the facts above named, which are sufficiently interesting to print.

"A few months since, the *Iron Age* printed a brief item crediting one of the largest metal merchants in the country with the statement that we would be exporters of tin plate in two years. The gentleman in question had exceptional opportunities for observation. But to the great majority in the trade the movement is most surprising, as tin plate is one of the few iron and steel products in the manufacture of which the American works were supposed to be still feeling to some extent the competition of foreign brands. The appearance of American tin plate in England will make the cup of bitterness more unpalatable than ever, which is now being held to the lips of the Welsh tin plate manufacturers.

"The progress which is thus shown to have been made in the American tin plate trade is almost beyond belief. Prior to 1890 no tin plate was made here, and the prospects for the establishment of a tin plate industry seemed very remote. After the enactment of the McKinley tariff a few small plants were started, but the business began in a discouragingly slow way. Many who had been ardent advocates of a high tin plate duty, in the belief that capital and skill were impatiently waiting to rush in as soon as the proper encouragement was afforded, were dismayed at the apparent apathy of the sheet manufacturers who had been expected to build tin plate factories as adjuncts to their mills. It was not until 1892 that the industry may be said to have really made a good start, and it was then seen that the builders of the new business would be largely men who had not been prominent in the sheet trade, and in notable instances not even connected with the iron trade. It may be claimed that in the comparatively short period of five years this country has not only built up a tin plate industry great enough to meet its own requirements, but of such strength as to appear tentatively in the markets of the world. The announcement of such an achievement must be gall and wormwood to those who persistently asserted, as late as 1894, that there were no tin plate factories in this country, and never would be.

"It is eminently fitting that the beginning of an export tin plate trade should be made by a company named the American Tin Plate Company. Wherever the products of that company may go they will constitute a proclamation of their origin in themselves.

"We have many euphonious names in the tin plate trade, and many exceedingly attractive names have been adopted to designate the various brands; but of all the list, none could so happily form pioneers in the foreign trade."

HIS SECRET DIED WITH HIM.

"In the death of Mr. Herbert E. Fowler, which occurred recently at Naugatuck, Conn., the secret of electrically depositing copper upon wood or other rigid or semi-rigid substance is said to have been lost. This process was made possible by coating the substance which was to be plated with copper with a liquid preparation, the secret of which was known only to Mr. Fowler. Every means had been used to induce him to patent the invention, but he declined to do so, fearing that he might lose the value of it in some way. The invention, it is stated, gave much promise of commercial value."

The foregoing statement is clipped from the pages of one of our leading electrical journals. It is a charitable presumption that the item was filled in as padding in response to the compositor's demand for copy. On no other supposition could so erroneous a statement be excused. The art of electroplating on wood, plaster compositions, and even on textile fabrics, is thoroughly well known to the trade, and is very widely practiced. W.

LONG-DISTANCE TELEPHONY AND THE RAILROADS.

The *Electrical Engineer* has the following of general interest:

"It does not seem within the scope of the ordinary human understanding, says the *Cincinnati Enquirer*, that the immense passenger traffic of a railroad of the marvellous extent of the Pennsylvania Company, or any similar line, could be visibly affected by the long-distance telephone. Such a statement ordinarily would be received with ridicule and laughter by the common railroad officials, and treated with contempt by the higher authorities. Yet, no lesser personage than James McCrea the head of the Western branches of the Pennsylvania system, told President M. E. Ingalls, of the Big Four and Chesapeake & Ohio Railroads, this week, that the business of the famous limited train of their company had been practically ruined by this instrument. These two gentlemen met yesterday in consultation in reference to commercial relations between the two lines, and during their negotiations the subject of the falling off of the passenger traffic of the country was brought up. Various reasons were given, when Mr. McCrea made his decidedly sensational statement. It is well known that the Pennsylvania Limited was originated and run in a measure for the benefit of the brokers and business men of Chicago and the Northwest, who needed quick action in the matter of travel. The trips to New York were taken upon occasions of utmost importance, when time meant thousands of dollars. By means of the Limited the broker or business man was taken to New York in the quickest possible way. There was no delay in getting there; it meant rapid business talk, and equally as quick a return to Chicago. The business man was willing to pay the price assessed for the development in rapid transit displayed by the Limited.

"Then came the introduction of the long-distance telephone. People were slow in realizing its benefit. Slowly but surely they have, however, acquired its significance. A broker in Chicago or a grain dealer in that city has an idea for a big deal; he telegraphs to New York asking for certain information: 'Call me up by long-distance telephone and give me your answer.' The result is that for $15, perhaps $20, a talk is held with the New York man. He has had an opportunity to concentrate his expressions to the shortest possible statement; he has even jotted it down, and at the proper time calls up his man and transacts business. So it is done every day. Mr. McCrea gave as an evidence that in the past he found it necessary to spend twenty days in the month on the road, leaving but ten days of his time at home. By aid of the long-distance telephone now he has reversed matters; it requires but ten days of his time upon the road, giving him twenty days at home. The matter, when it came to the attention of an *Enquirer* representative, was presented to various business men upon the Chamber of Commerce and upon Third Street. Half a dozen grain men, who have been in the habit of making two and three trips a week to Chicago, said: 'Oh, yes, that has been the case with me; I have, for $3 or $4, been able to transact business which otherwise meant a trip to Chicago or St. Louis.' The same way with commission dealers and brokers. They indorsed the statements of the grain men, and stated that the telephone had saved them numerous trips. The financial brokers and bankers of Third Street use the telephone continually now; in fact, it is quite the feature of several of the more prominent brokers since they have their long-distance telephone connections, but it has never become so prominent a factor in railway circles as has been stamped by Mr. McCrea's utterances. If it practically interferes with a great train like the Limited, a revolution is certainly taking place in railroad affairs."

THE MULHOUSE INDUSTRIAL SOCIETY'S PRIZES.

The Société Industrielle de Mulhouse gives two principal prizes of 5,000 francs each, at intervals of ten years, for discoveries or inventions held to be most usful to Alsatian industries. The next award of one of these prizes will be made in 1899. Other prizes, principally medals, are annually awarded for less important advances in the industrial arts, while money prizes are awarded to workmen, with a view to encouraging the growth of economy and the family affections among them. Among the next awards of interest to engineers is a medal and 500 francs for the best memoir on a new and advantageous method of constructing factory buildings. A medal is offered for a boiler, giving an efficiency of 80 per cent., capable of being worked efficiently at varying outputs, and to cost for maintenance not more than elephant boilers of the same power. Another medal is offered for a satisfactory integrating indicator. Similar awards are offered for new and reliable methods of steam heating, and for large gas engines, while medals and money prizes of 500 francs each are offered for a research on the flow of steam in pipes and for a self-registering pyrometer.

BOOK NOTICES.

Engineering Contracts and Specifications, including a brief synopsis of the law of contracts, and illustrative examples of the general and technical clauses of various kinds of engineering specifications. Designed for the use of students, engineers and contractors. By J. B. Johnson, C.E., Professor of Civil Engineering, Washington University, St. Louis, Mo.; member of the Institution of Civil Engineers; member of the American Society of Civil Engineers; member of the American Society of Mechanical Engineers, etc. Engineering News Publishing Company, New York. Price, $4.00.

Schools of engineering are frequently, perhaps justly, charged with failure to provide their students with a working knowledge of the practical side of the engineering profession.

In this volume Prof. Johnson has taken a notable step toward lifting this reproach. In furnishing an admirable and much-needed discussion of the matters embraced in the title, he has performed a valuable service, not only to the students, but to the practising engineer.

It is, perhaps, a matter of congratulation, that, as stated in the preface, "the author makes no pretension to a knowledge of the law;" for, in law, as in other matters, it is apt to be the layman who can best appreciate his fellow-laymen's difficulties, and who can best decide and supply what they require. While the reader is referred to his attorney, or to treatises on law, for advice and information in important cases, the author, who "has attended lectures in this field in the St. Louis Law School (a department of Washington University)," appears to have succeeded admirably in giving an outline of those legal *principles* with which every engineer should be familiar.

The sample specifications, which usually make up a large portion of such works, are well chosen from the modern practice of noted American engineers, and carefully edited; but the chief merit of the work is in its very thoughtful discussion of the engineering and legal principles underlying the many general and specific clauses of which specifications are necessarily made up.

The work bears, throughout, the impress of careful, intelligent and conscientious labor, and those who have occasion to prepare specifications for important work cannot afford to be without it. J. C. T.

A Text-book of the Principles of Physics. By Alfred Daniell, M.A., etc. (Third Edition). New York: Macmillan & Co. John Wanamaker, Philadelphia.

Daniell's work is one of the few treatises on physics which have received general recognition as standard text-books in English.

The edition above named is the latest, and it will be found to contain an exposition of the principles of the science, in the light of the most recent advances made therein. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 17, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 17, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 102 members and visitors.

Additions to membership since last report, 25.

The President made some remarks on the approaching completion of the work of stacking the library in the newly arranged fire-proof quarters that have been prepared for the purpose, and urged upon the members the desirability of bringing the change to the notice of their friends.

Mr. Chauncey N. Dutton, of New York, was introduced by the President as the first speaker of the evening. Mr. Dutton gave a description, illustrated with the aid of a working model and numerous detail drawings, of a pneumatic lock for canals, involving a system and apparatus of his invention.

The remarks of the speaker were devoted specially to a lock of this character (62½ feet lift) which he had designed for Lockport, New York, and which had been approved by the Canal Commissioners of the State of New York. The subject evoked a lengthy discussion, participated in by Messrs. E. A. Scott, Spencer Fullerton, G. M. Eldridge, Joseph Richards, Theo. D. Rand, the President and Mr. Dutton.

On Mr. Fullerton's motion, duly seconded, the subject of the paper was referred to the Committee on Science and the Arts for investigation and report.

Mr. Wm. C. Henderson, by invitation, presented a communication "On Kryolith, its Mining, Preparation and Utilization." The communication was illustrated with the aid of a series of lantern slides.

The Seçretary called attention to a method of determining the density of smoke from furnace chimneys, devised by Dr. Ringelman, and illustrated the system with the aid of a lantern slide.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held November 3, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

Perpetual Power with Manageable Air-Ship, J. A. Klefler, Philadelphia
The Duplication of the Cube, Charles Morrell, Chicago, Ill.
Investigations with the Electric Furnace, Henri Moissan, Paris, France.
Improvements in Tidal Powers, Ernst Markmann, Philadelphia.
"Franklin Medal" Foundation (Institute).

Reports on the following subjects were adopted :

All-Wrought-Steel Pulley, Thomas Corscaden, Philadelphia. Reserved for publication in full.

Percussion Wheel.—Francis M. F. Cazin, New York.

ABSTRACT.—This invention applies to water-wheels of the percussion type, and the improvements relate to the crown of the wheel, to the water-buckets to be connected in pairs to the said crown, and to the manner of connecting these pairs of buckets with the said wheel crown.

More specifically :

(1) The improvements relate to the peculiar form given to the concavity of each bucket, for the purpose of securing to the water-jet, striking them under head, a regular curved or segmental line of contact in whichever of the possible directions the water may strike them while they recede from the nozzle as the wheel is revolving ; and

(2) To the arrangement of pairs of these buckets to the effect of being in immediate contact with one another as pairs, each of the pairs having the same regular cavity, with no division or interruption by a ridge or projection, and with no difference to distinguish between them as right and left, with no cutting away of either front or side walls, and with no rim or wheel-ring or wedge between them, but provided with a superstructure by which the jet is divided into halves even before it touches the buckets ; all for the purpose of effecting such a division of jet on as sharp an angle as possible.

The report finds that the Cazin improvements do not embrace the principles upon which the wheels known as impact wheels, jet-wheels, etc., operate, but are confined to the construction of the buckets and the application of the jet by which provision is made.

(1) For dividing the jet on a line parallel with the shaft of the wheel, and this first division into another and inner part, this being so precisely regulated that, while the top of each vane causing the first division passes through the jet, the interrupted inner part is guided into the vane and is—

(2) There divided into halves on a line at right angles to the first (top) line of division, and in the central plane of rotation, being then distributed between two bucket cavities, where each half is made to serve the purpose of force transmission by being uninterrupted by and completely immersed in its direction of flow on true curves.

Applicant claims that the form and arrangement of buckets adopted by him are derived from mathematical calculations, and that by their use only can there be accomplished the complete and permanent inversion of flow of force jets. The constructive lines thus developed by the applicant have been made the subject of letters-patent of the United States, No. 578,812, March 16, 1897.

In the absence of data derived from comparative tests of efficiency of the Cazin and other forms of impulse wheels, and in view of the circumstance that circular lines for buckets have long been known and described in treatises on hydraulics as the ideal form to realize a complete inversion of the jet, the sub-committee charged with this investigation fails to find ground for a favorable report. [*Sub-Committee.*—Wm. M. Barr, Chairman ; John E. Codman, Chas. G. Darrach, Henrik V. Loss.]

Balanced Locomotive Driving Wheel.—Philip Z. Davis, Philadelphia.

Abstract.—This applicant claims a system of balancing for the revolving and reciprocating parts of a locomotive driving-wheel, consisting in the use and special disposition of two counter-weights. The arrangement is disclosed in U. S. letters-patent Nos. 578,597–8 and 9, dated March 9, 1897, to which reference is made for details, of which it is difficult to make an intelligible abstract.

The report of the Sub-Committee is unfavorable to the applicant's claims, and concludes with the statement that "the problem of counter-balancing the reciprocating parts of a locomotive and the revolving parts at the same time, is as far from solution as ever." [*Sub-Committee.*—Wilfred Lewis, Chairman; Henry F. Colvin, Hugo Bilgram, S. M. Vauclain, Wm. P. Evans.]

Combination Book-Shelf and Book-Support.—August Lundberg, Worcester, Mass.

Abstract.—This is a movable book-support to be used on book-shelves to keep a row of books upright when the shelf is not full. It is made of sheet metal, bent at right angles, the one part to stand vertically for the book to rest against, and the other to lie flat upon the shelf, and upon which the weight of the book or books rests. The special difference between the Lundberg invention and others of its class consists in the fact that it does not depend upon the weight of the books to keep the support in the right position to hold the books upright, but has the horizontal arms formed of metal sufficiently thick to allow them to act as tongues to traverse in grooves formed on the face of the shelf, to make the support slide always parallel with the length of the shelf, and to keep the support from being pushed backward or forward by the removal or insertion of books.

The report finds that the Lundberg modification is not a desirable one, for the reasons that it adds both to the cost of constructing the shelves and of the support itself, and would make the shelves more destructive to the books. [*Sub-Committee.*—Henry R. Heyl, Chairman; Spencer Fullerton.]

Pneumatic Pyrometer.—Uehling & Steinbart Co., Ltd., New York.

The object of this invention is to produce an instrument for accurately and continuously indicating high temperatures. The principle involved is the law of the passage of gas or air under a constant forced flow through small apertures. In the provision of a device for effecting this object, its primary feature is the forcing of air or gas through two successive small apertures, whereby the tension between them will remain constant so long as the temperature of the passing fluid remains equal and constant at both apertures, and whereby a change of temperature at either one or the other of the apertures will also cause a change of tension between them. If, therefore, the fluid as it passes through one of these apertures is made to vary with the temperature to be measured, while at the other it is constantly kept at a certain normal temperature, then the variation of the tension between the apertures will be a measure of the degree of heat the air has at the time of entering into the space or conduit between and connecting the two apertures, and hence of the temperature to be measured. For carrying out this operation and obtaining this result, the invention consists of certain novel parts and combinations of parts, for the detailed account of which reference is made to the full text of report, or to U. S. letters-patent granted to Edward A. Uehling and Alfred Steinbart, No. 11,413, April 17, 1894.

The report of the sub-committee finds that the principle on which this pyrometer acts is theoretically correct, and has not heretofore been applied to this purpose, and that the instrument in actual use is very satisfactory. The John Scott award is therefore recommended. [*Sub-Committee.*—H. W. Spangler, John Hartman, A. E. Outerbridge, Jr.]

Holophane Globes.—Geo. A. Macbeth Company, Pittsburgh, Pa.

ABSTRACT.—The object of this invention is to secure diffusion of the light by means of a transparent globe of such construction as to insure that the light usually lost by being sent off into the space above the horizontal plane passing through the source of the light, shall be distributed in the space below that plane and thus be made useful. To effect this result the principles of reflection and refraction are called into service, and the contour of the globe is given a form such that these principles are made available.

The details of the special construction of these globes cannot be intelligently understood without the aid of illustrations, and the reader is accordingly referred to the full text of the report, or to the letters-patent of the United States, No. 563,836, July 14, 1896, granted to the inventors, Messrs. Andrée E. Blondel and Spiridion Psaroudaki, of Paris, France.

The report of the investigating sub committee finds that MM. Blondel and Psaroudaki have invented a globe that secures much better diffusion and more satisfactory distribution of light than any other globe known to the committee; that its manufacture on the commercial scale has been satisfactorily accomplished, and that the invention has made a distinct improvement in the diffusion and distribution of artificial light.

The John Scott award is therefore recommended to the inventors. [*Sub-Committee.*—George A. Hoadley, Chairman; George F. Stradling, George U. G. Holman, Edward A. Partridge, George Strawbridge, Clayton W. Pike.]

SECTIONS.

MINING AND METALLURGICAL SECTION.—Stated meeting November 10, Mr. Benj. Smith Lyman, President, in the chair.

Mr. John Gifford, Princeton, N. J., presented a communication on "Forestry as Related to Geology and Engineering."

Mr. Wm. C. Henderson, Secretary of the Section, read a paper on "Kryolith: its Mining, Preparation and Utilization," illustrated with lantern projections of views of the mining of kryolith at Ivigtut, Greenland, and with specimens of the raw material, and various products manufactured therefrom.

CHEMICAL SECTION.—Stated meeting November 16th, Dr. Lee K. Frankel in the chair.

Dr. Bruno Terne read a paper on "Ammonia and its Sources."

ELECTRICAL SECTION.—Stated meeting November 23d, Mr. Clayton W. Pike, President, in the chair.

Mr. W. E. Harrington read a paper on "Railway Bonding."

Mr. J Lester Woodbridge, of New York, addressed the Section on "The 'Booster' System as Applied to Electric Railways."

[The papers above-named will appear in full in the *Journal* in due course.]

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